The effectiveness of puppetry art in changing learners' attitudes in Natural Sciences

By

Valentine Ukachukwu Okwara

M.Ed. (UFS), Honours B.Ed. (UFS), P.G.C.E (FET) UFS, P.G.D.I.S (ABSU, Nigeria), B.Sc. Zoology (ABSU, Nigeria)

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Supervisor: Professor JPH Pretorius

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Declaration

I, Valentine Ukachukwu Okwara, declare that the thesis, The effectiveness of puppetry art in changing learners' attitudes in Natural Sciences, submitted for the qualification of Doctor of Philosophy (Ph.D.) at the University of the Free State, is my own independent work.

All the references that I have used have been indicated and acknowledged by means of complete citations.

I further declare that this work has not previously been submitted by me at another university or faculty for the purpose of obtaining a qualification.

2021/07/13

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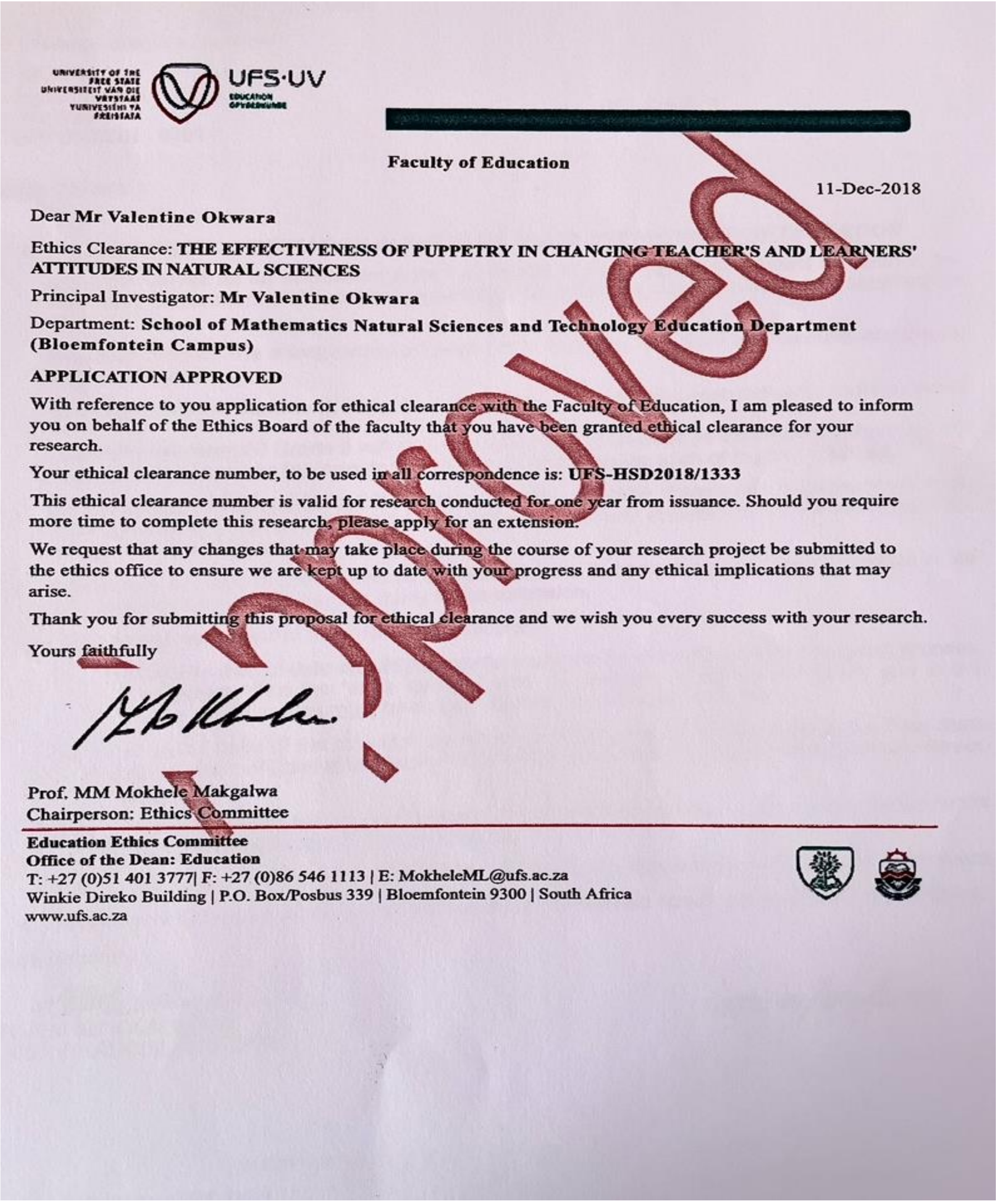
SIGNED DATE

Ethical clearance letter



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11-Dec-2018

Dear **Mr Valentine Okwara**

Ethics Clearance: **THE EFFECTIVENESS OF PUPPETRY IN CHANGING TEACHER'S AND LEARNERS' ATTITUDES IN NATURAL SCIENCES**

Principal Investigator: **Mr Valentine Okwara**

Department: **School of Mathematics Natural Sciences and Technology Education Department (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2018/1333**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Prof. MM Mokhele Makgalwa
Chairperson: Ethics Committee

Education Ethics Committee
Office of the Dean: Education
T: +27 (0)51 401 3777| F: +27 (0)86 546 1113 | E: MokheleML@ufs.ac.za
Winkie Direko Building | P.O. Box/Posbus 339 | Bloemfontein 9300 | South Africa
www.ufs.ac.za

Letter from language editor

To whom it may concern

This is to state that the Ph.D. thesis titled *The effectiveness of puppetry art in changing learners' attitudes in Natural Sciences* by Valentine Ukachukwu Okwara has been language edited by me, according to the tenets of academic discourse. The final responsibility to implement any suggested language changes resides with the student.

Annamarie du Preez

B.Bibl.; B.A. Hons. (English)
06-07-2021

Abstract

The declining attitudes of learners towards science over the years has been a source of concern to educationists. Researchers has shown that learners' attitudes towards science can be influenced by the type of tool or strategy the teacher employs to deliver the lesson in the classroom. This study aims to determine the effectiveness of puppetry art as a teaching tool to change the attitudes of learners towards natural sciences within the context of the STEAM educational approach. The study was conducted at three different schools in the Motheo District of the Free State province. The participants were Grade 9 learners who were selected by random sampling and placed in three experimental and control groups. The study employed a quantitative research methodology and the experimental research design method. Data was obtained through pre-tests and post-tests using a standardised attitude survey, the Colorado Learning Attitudes about Science Survey (CLASS). Descriptive and inferential statistics were used in the analysis of the data, while the analysis of covariance (ANCOVA) was employed to adjust the dependent variable to remove the effects of the uncontrolled sources of variation represented by the concomitant variable in the test of the null hypothesis. The results showed that the learners' personal interest, conceptual understanding and applied conceptual understanding categories regarding their attitude towards natural sciences were positively influenced by the application of the teaching tool. The learners' sense-making effort, general problem-solving confidence, and sophistication, as well as the real-world connection categories regarding their attitude towards natural sciences were not influenced by the teaching tool. Further research is needed to focus on ways to improve the implementation of the application of this teaching tool for improved learner performance, as well as their change in attitude towards science.

Keywords

Attitude change, learners' attitudes, puppets and puppetry art, STEAM approach, personal interest, conceptual understanding, applied conceptual understanding

Dedication

This Ph.D. thesis is dedicated to the following, for the various impacts they have had on my life, which remains eternally with me.

Mr. Michael Izuagba Okwara, B.A. (GEN) London. An astute educationist and philanthropist who overcame life's challenges to graduate from the University of London in 1968. I owe my success to his inspiration, my humble Dad.

Nneoma Virginia Michael Okwara (*Nneoma nwere ugwu* of Orlu diocese), a rare gem, a disciplinarian, pillar of strength, and my teacher, I owe everything to her, she will reign eternally in my heart, my darling Mom.

Gloria Setshego, my amiable wife, Michael II, Nkosinathi and Oratile, my boys, you have been my pillar of strength, Dad loves you all.

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My gratitude goes to Professor Jannie PH Pretorius, of the school of Mathematics, Natural Science and Technology, faculty of Education, University of the Free State, my erudite supervisor, for his amazing guidance, support and team leadership during the course of the study, you are truly a great leader and a source of infinite inspiration, thank you "Prof. J" as I fondly call him. Also, Professor Robert Schall of the Department of Mathematical Statistics and Actuarial Science (UFS) for the statistical analysis of the research data, thanks a lot Prof. My wife and best friend, Gloria Setshego Okwara (Nnem Oma), for all her inspiration and support during the study. I would also wish to thank Mr. Lebogang Lesiu, "my boss" as I fondly refer to him, for all his encouragement and support during difficult times, I really appreciate you. Sherica Matsoaboli, Thabo Mondi and Lehlohonolo Chobokoane (my puppeteers) for their amazing role and support during the data collection field work. All the Grade 9 learners who sacrificed their Saturdays to participate in the study. The principals and natural science educators from the schools where the study was conducted for their cooperation and support. The research unit of the Free State Department of Basic Education (FSDoE) for granting me the permission to conduct the study. The ethics committee of the University of the Free State for endorsing the conduct of the study. The language editor who fine-tuned the thesis, as well as the printer and binder who gave it a finishing touch. I would also like to acknowledge my family for all their support. Finally, am very grateful to God almighty, through the intercession of the most blessed Virgin Mary mother of Jesus Christ for the successful completion of this study.

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List of Acronyms

Acronym	**Meaning**
Pers_int	Personal interest category of the learners' attitudes
Conc_under	Conceptual understanding category of the learners' attitudes
Appl_conc_under	Applied conceptual understanding category of the learners' attitudes
SME	Sense-making effort category of the learners' attitudes
PS_general	General problem-solving category of the learners' attitudes
PS_confidence	Problem-solving confidence category of the learners' attitudes
PS_sophist	Problem-solving sophistication category of the learners' attitudes
RWC	Real-world connection category of the learners' attitudes
FSDoE	Free State Department of Basic Education
FET	Further Education and Training
GET	General Education and Training
STEAM	Science Technology Engineering Arts and Mathematics
STEM	Science Technology Engineering and Mathematics
TPB	Theory of Planned Behaviour
ANCOVA	Analysis of covariance
CHAT	Cultural Historical Activity Theory
TIMSS	Trends in International Mathematics and Science study

CHAPTER ONE

BACKGROUND, PROBLEM STATEMENT, RESEARCH DESIGN AND METHODOLOGY

1.1 Introduction

Learning science is a process of acquiring scientific skills, knowledge, attitudes and values (Blackman, Conrad & Brown 2012:160). The approaches, strategies and tools the teachers use to engage with the content may influence the attitudes of learners towards science (Blackman et al. 2012:160). Attitudes can be defined as mental entities that have a profound impact on peoples' behaviour (De Houwer, Gawronski & Barnet-Holmes 2013:253). Attitudes are therefore important in determining the interest to teach or learn (Yan & Sin 2015:216).
This implies that the attitudes of teachers and learners towards science determine how they perceive it (Dohn 2016:188). The importance of attitudes in the teaching and learning of science is further emphasised by Van Aalderen-Smeets, Van der Molen, Van Hest and Poortman (2017:238), who stated that promoting the learners' interest in studying science requires a positive attitude.

Learners' attitudes towards science in schools have been on the decline (Barmby & Kind 2008:1078). This decline in attitudes towards science subjects have been a cause for concern (Kennedy, Lyons & Quinn 2014:34). Therefore, an understanding of learners' attitudes towards science, and how these can be changed over time, is of importance in stemming this decline (Kennedy et al.

2016:422). According to the Trends in International Mathematics and Science Study (TIMSS), in 2019 South African average score in science was 370 points compared to over 400 TIMSS points that show basic science knowledge for grade 9 learners. South Africa still has a long way to go to improve science basic knowledge (Reddy, Winnaar, Juan, Arends, Harvey, Hannan, Namome, Sekhejane and Zulu 2019:5). This is an indication that the learners' attitudes towards science needs to change amongst other factors in order to improve science learning.

STEM is an acronym for Science, Technology, Engineering and Mathematics. Over the past decade, the move to include the arts in STEM education has gained momentum, making Science, Technology, Engineering, Arts and Mathematics (STEAM) a more meaningful platform to deliver holistic instruction in the science classroom (Costantino 2017:1).

The goal of this trans-disciplinary approach, STEAM, is aimed at powerful, authentic learning opportunities which can help the learners to tackle challenging circumstances in the future (Jamil, Linder & Stegelin 2017:1). The inclusion of the arts in STEM activities delivers a natural platform for transdisciplinary inquiry (Quigley & Herro 2016:410). STEAM education therefore aims at increasing the learners' efficacy, confidence, and interest in science (Kim & Chae 2016:1925), because the arts incorporate new approaches to solving problems.

According to Kim and Chae (2016:1926), recent developments in science and technology has led to an increase in globalisation, convergence and unpredictability, causing the need for future scientists to develop creative problem-solving and global expertise rooted in an arts education. The shift therefore from STEM to STEAM will have a positive effect on the learners' learning (Yuksekyalcin, Tanriseven & Sancar-Tokmak 2016:220) because the arts embody creativity which may enhance science learning (Sousa & Pilecki 2013:24).

In view of this, the study aims to determine the effectiveness of puppetry art in changing the attitudes of learners towards the learning of natural sciences. The use of arts (puppetry) in the teaching and learning of natural science may stimulate the interest of the learners, thereby motivating them and enhancing their cognitive abilities (Remer & Tzuriel 2015:364). This is because both science and the arts require discovery, observation, experimentation, description, interpretation, analysis, and evaluation (Fulton & Simpson-Steele 2016:2).

STEAM incorporates the arts to enhance science education through exposing learners to subjective views of the world as a compliment to the objective view offered by science (Sousa & Pilecki 2013:10). Researchers, therefore, have argued that the arts have the ability to help learners draw on curiosity, observe accurately, work effectively with others, think spatially, and perceive aesthetically (Sousa & Pilecki 2013:11).

Puppetry art is a form of arts which presents a medium of instruction that incorporates entertainment into learning, making it easier to communicate across a wide range of cultures and languages (Remer & Tzuriel 2015:365). This can be attributed to the combination of various disciplines, such as theatre arts, visual arts, storytelling and oftentimes music and drama (Quintero 2015:1). This combination is vital for communication, education and teaching in the science classroom, as it enables the learners to express their feelings and thoughts, which otherwise would have been hidden.

In a study by Remer and Tzuriel (2015:358) in which they used puppets as a mediatory tool in the teaching of mathematics, they noticed that all the learners were meaningfully engaged and participated actively. Even the shy and reclusive learners also participated in the lesson. This observation could be attributed to the level of engagement the learners had with the puppets, which stimulated their positive attitudes toward the lesson.

Puppetry and puppets have often been used in television programmes to illustrate stories and entertain children, which enliven their imagination (Soord 2008:1; 38). Puppets enhance the learning process, as they involve a variety of significant linguistic interactions which encourage conversation among learners with language difficulties (Remer & Tzuriel 2015:564).

In addition to these applications of puppetry, Smith (2015:533) observes that puppets have their own power and influence as metaphysical objects, which can be applied to contextualised situations to enhance cognition. Alluding to Smith's observations, De Beer, Petersen and Brits (2018:178) found that using puppetry as a tool in the science classroom, addressed affective learning outcomes (attitudes) and held the key to enhanced self–directed learning.

This can be attributed to the ability of learners to write their own scripts, which requires epistemological border crossing and creative thinking. This may lead to the development of scientific communication skills across various scientific boundaries, thus enabling the learners to have a change of attitude towards the relevance of science in their everyday lives.

1.2 Research focus

The main focus of this study is to investigate and determine an account of how the attitudes of learners towards the learning of natural sciences might be positively influenced by the use of puppetry art as a teaching tool in the classroom. An additional focus is to formulate recommendations and/or guidelines on the effectiveness of puppetry art as a tool in the teaching and learning of natural sciences within the context of the STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach.

1.3 The conceptual framework

Ajzen's theory of planned behaviour incorporates the combined effect of attitudes, subjective norms, and behavioural control in understanding the reasons for human behaviour (Ajzen 1991:182). The theory explains how intentions and behaviour (for example, teaching and learning science), are functions of three basic factors: (a) attitudes (b) subjective norms and (c) perceived behavioural control (McGregor &

Knoll 2015:338). The theory will be adapted as the conceptual framework for this study. The resulting framework is presented in Figure 1.1 below.

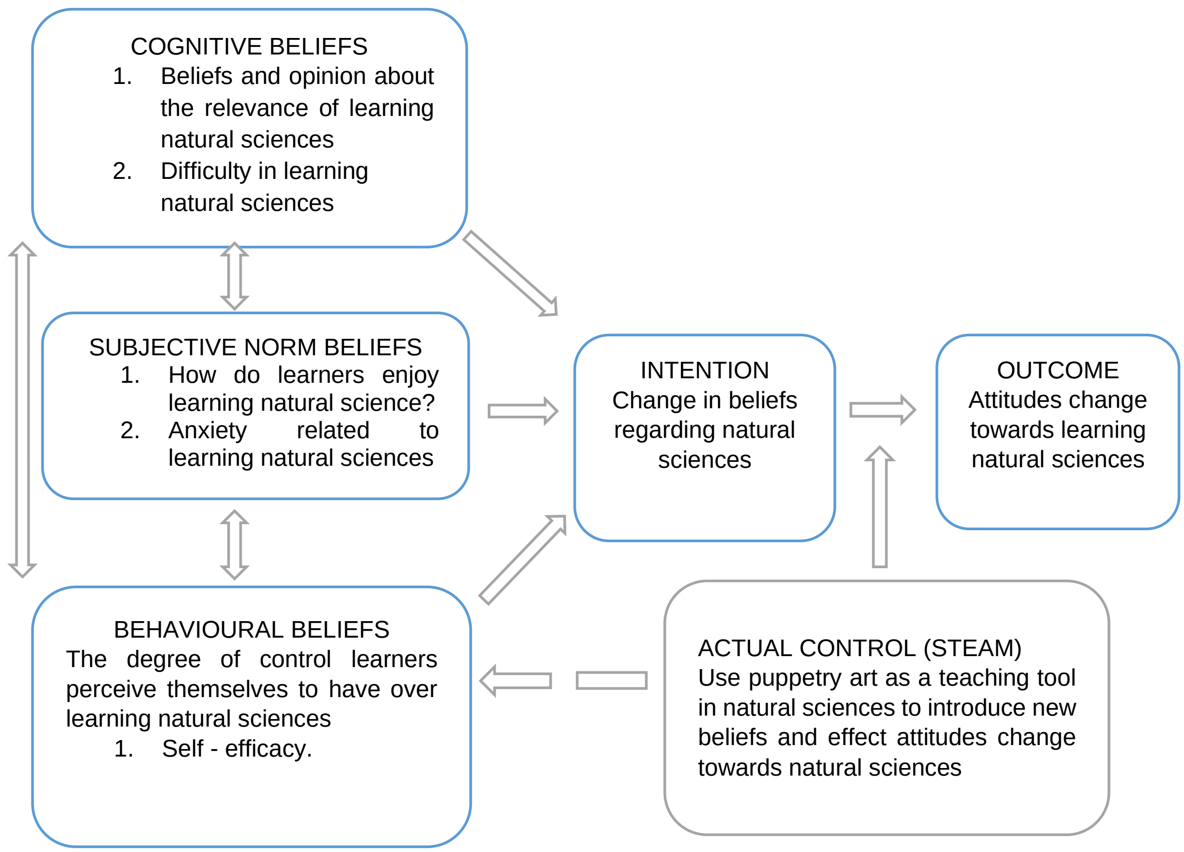

Figure 1.1 Conceptual framework on learners' attitudes towards natural sciences (Ajzen 2019:1).

According to Ajzen and Sheikh (2013:155), the attitude factor explores learners' attitudes towards learning science. Positive attitudes towards learning science can be explained in terms of sustained learner engagement with the content due to teachers' use of strategies designed to enhance understanding and participation in learning activities. Good learner/teacher interaction also facilitates this (Yung, Zhu, Wong, Cheng & Lo 2013:2451).

The subjective norms can be explained in terms of learners' declining interest in learning sciences, and the teachers' difficulty in making science lessons more exciting in the classroom. The perceived behavioural control in the context of this study can be explained in terms of inadequate teaching strategies to make learning science more interesting (Yung et al. 2013:2452). The intention therefore will be to determine and develop the use of puppetry art as an alternative teaching tool to make science more interesting, and achieve the desired change in attitude towards the teaching and learning of sciences within the context of STEAM education (McGregor & Knoll 2015:339).

As Braund, Ekron and Moodley (2013:5) point out, drama is one of the methods in socio-cultural and socio-linguistic traditions that can lead to active teaching and learning in science. According to research, learners learn best through active participation and interaction with the teacher and other learners in the learning process. Active participation means that learners are cognitively and meaningfully engaged with the learning content (Chi & Wylie 2014:219).

In theory, one of the learning approaches that might be applied to address the shortcomings of traditional rote learning methods is the use of the arts to make the teaching and learning of natural sciences more meaningful (Sousa & Pilecki 2013:31). The application of puppetry art as a teaching tool therefore may increase learners' motivation to learn. This is because puppetry is a form of art that promotes creativity (Sousa & Pilecki 2013:24). Its application as a teaching and learning tool may ease the perceived difficulty in learning natural science concepts (Hassan 2018:2046) and promote attitude changes (Sousa & Pilecki 2013:75; Lindquist, James-Hassan & Lindquist 2017:92). Creating puppetry art–integrated lesson plans in ecology might therefore promote collaborative culture and creativity, which might further promote learners' learning experiences (Liao 2019:38) by reinforcing their attitude change towards natural science.

Negative attitudes follow automatically and consistently from learners' beliefs regarding their ability to learn (Ajzen 2011:1116). Since attitudes are assumed to form the basis of beliefs, behavioural interventions should try to change those beliefs by introducing new beliefs that, according to the theory of planned behaviour, TPB, might ultimately lead to attitude changes (Ajzen 2011:1116) with regards to natural sciences.

It might be easier to produce changes in the attitudes of the learners by introducing an intervention designed to lead to the formation of new beliefs than it is to change existing beliefs (Ajzen 2019:4). Only when the balance in beliefs in all the three major predictors of attitude shifts in the desired direction, can we expect changes in attitude (Ajzen 2019:4) towards natural sciences. These determinants of attitudes have been found by research to shape the attitudes of learners (Ajzen 2019:5) toward natural sciences. According to Ajzen (2019:4), in order to introduce new beliefs and influence attitude change, the strength of the old beliefs the subjects might hold, should be tackled through approaches designed to lead to the formation of new beliefs.

One of the teaching approaches that might be used to tackle the strength of the old beliefs leading to the formation of new beliefs, as prescribed by Ajzen (2019:4), is the use of puppetry art as a teaching tool within the context of the STEAM educational approach. This might lead to the formation of new beliefs at the cognitive, normative and behavioural levels, thereby influencing learners' attitude change towards natural sciences. According to Ajzen (2019:5), therefore, the application of puppetry art as a teaching tool in natural sciences might produce these possible outcomes in their cognitive, normative and behavioural determinants of attitudes as discussed below.

Cognitive beliefs: the use of puppetry art as a teaching tool in natural sciences might facilitate the introduction of new beliefs on the perceived relevance of the subject because it introduces a different style of interpersonal relationships which is quite productive for science learning (Simon, Naylor, Keogh, Maloney, & Downing, 2008:1231). It also aids instructional scaffolding (Simon et al. 2008:1246; Lindquist et al. 2017:92), which has the potential to make a positive impact on the perceived relevance of the subject. This is crucial for the guided construction of knowledge (Simon et al. 2008:1246; Belohlawek, Keogh & Naylor 2010:36-37).

This might enable the learners, during peer group interactions, to have different opportunities for cognitive development, due to their exposure to reasoning that is more superior to their own (Simon et al. 2008:1241). This might ease the perceived difficulty in learning natural sciences (Hassan 2018:2046), leading to an attitude change towards the subject.

Normative beliefs: the use of puppetry art as a teaching tool might introduce new beliefs on how the learners enjoy natural science lessons. This can be attributed to the influence of the puppets on the learners' attitudes through their appearance, movement, speech, and action (Ahlcrona 2012:172). The power of the puppets to evoke thoughts, associations, feelings and intentions in their interaction with the learners during the natural science lesson, and afterwards, in the form of recollections (Ahlcrona 2012:173), might change the way they enjoy natural science lessons.

Moreover, the puppets might also have an influence on their affective domain, which embodies feelings that can be transformed into an action, thoughts or interactions (Sloan 2018:585). This transformation might have a powerful influence (Sloan 2018:584) on how they enjoy natural sciences lessons by enabling the learners to easily develop an understanding and construct natural science skills and knowledge and overcome their fears and anxiety concerning the learning of natural sciences concepts (Lindquist et al. 2017:91; Sasway & Kelly 2020:2). Such fears and anxiety may prevent them from enjoying natural sciences lessons. This might also have a profound influence in introducing new beliefs on how they enjoy ecology lessons, resulting in a possible attitude change towards the subject.

The use of puppetry art as a teaching tool in natural sciences might introduce new beliefs that address learners' feelings of low self-efficacy. This might enable them to perform communication acts based on knowledge–related and emotional motives that overstep the boundaries between actual and imagined worlds (Ahlcrona 2012:180). Ahlcrona (2012:172) describes the power of puppets, when applied in the context of the teaching and learning of science, as able to evoke and arouse learners' emotions, thoughts and associations, which might positively impact on their attitudes. It may also lead to recollections, which might consolidate their learning (Ahlcrona 2012:173).

This might improve their self-efficacy and make the learning of natural sciences more interesting and meaningful (McGregor & Knoll 2015:339). Puppets are familiar figures that might influence the imaginary world of the learners and improve their creativity (Güçlü & Çay 2017:130). This, in turn, may lead to the introduction of new beliefs that might address their low self-efficacy and inspire the desired change in their attitude towards natural science.

According to Ajzen's stipulations, the application of puppetry art as a teaching tool in natural sciences, therefore, might enable inspiration and novelty as well as the development of cognitive and social growth (Sousa & Pilecki 2013:29). This might enhance creativity, reduce stress, and make natural sciences lessons more enjoyable (Sousa & Pilecki 2013:29). The STEAM educational approach incorporates the arts to enhance science learning through exposing the learners to subjective views of the world as a compliment to the objective view offered by science (Sousa & Pilecki 2013:10; Kim & Chae 2016:1928).

1.4 The cultural-historical activity theory (CHAT) as the theoretical lens

According to the CHAT, the primary unit of analysis for understanding human knowledge and practices is a collective artefact-mediated and object-oriented activity system. In this system, the individual and group actions are subordinate units of analysis, understandable only when interpreted against a background of the entire activity system (Engeström 2001:136). Within this context CHAT views activity systems as the central and determining factor regarding human learning and knowledge construction (McMurtry 2006:209). The cultural-historical activity theory (CHAT) therefore allows us to think in new and productive ways about individual development generally (Roth 2012:96) and about the learners' attitude change towards natural sciences specifically.

My approach in this study, therefore, is to apply Engeström's third generation cultural-historical activity theory (CHAT) activity systems as a lens through which to view the research objectives and the resultant findings. According to Roth (2012:90), activity is the basic category of the cultural-historical activity theory (CHAT). It is the smallest analytic unit for understanding human performances, their practices, the sense they make or the actions they perform. Activities are therefore concretely realised by goal-directed actions, but actions are performed because they realise an activity (Roth 2012:91).

The CHAT activity system is concerned with human knowledge and practices (Roth, Lee & Hsu 2009:132). It has been described as a multifaceted clarifying tool, capable of being utilised in a variety of disciplines to understand and analyse human learning as well as changing the conditions in which we learn (DiSarro 2014:438). In this context, it will provide the theoretical basis for the argument on the application of puppetry art as a teaching and learning tool in natural sciences within the context of the STEAM educational approach (Foot 2014:330).

Previous research indicates that learners' attitudes towards science are declining (Osborne, Simon & Collins, 2003:1050; Kind, Jones & Barmby 2007:26; Barmby & Kind 2008:1078; Kennedy et al. 2014:34; Villafuerte, Serrato & Zavala 2015:477; Fernández Cezar & Solano Pinto 2017:112; Reddy 2017:26). This trend has not changed in South Africa according to the TIMSS report of 2019 (Reddy, Winnaar, Juan, Arends, Harvey, Hannan, Namome, Sekhejane and Zulu. 2019:5). This decline may be attributed to many factors, including science subjects perceived as much more difficult (Wan & Lee 2017:508) due to ineffective teaching methods (Mujtaba, Sheldrake, Reiss & Simon 2018:645).

According to Daniels (2001:70), learning is socially constructed through the collaborative efforts of the teachers and the learners, in order to achieve shared objectives in specific cultural surroundings. Therefore, the integration of puppetry art as a tool in natural sciences learning within the context of the STEAM educational approach might provide the much-needed creativity, critical thinking and problem-solving skills (Sousa & Pilecki 2013:11) needed to activate an attitude change from the learners' side towards natural sciences because researchers have found that the attitudes of learners towards science has been declining over the years (Barmby & Kind 2008:1078).

1.5 Research problems, research questions and hypothesis

Barmby and Kind (2008:1078), in their research in the United Kingdom, found that the attitudes of learners towards science in high schools were declining. Learners' consistent lack of interest in science might be attributed to their inability to apply scientific knowledge due to traditional and ineffective teaching methods. According to Abell, Park, Rogers, Hanusein, Lee and Gagnon (2009:79), the content knowledge of the science teacher is not necessarily a condition for effective teaching, but rather a combination of effective teaching strategies. Braund et al. (2013:12) highlighted the importance of exploring opportunities to develop teachers in the effective use of drama as a teaching strategy in order to develop their skills and positive attitudes towards science. According to Anderson, Anderson, Varank-Martin, Romagnano, Bielenberg, Flory and Whitworth (in Rollnick, Dlamini & Bradley, 2015:1203), traditional teaching methods are no longer effective in the improvement of learners' ability to apply scientific knowledge and think critically.

How the learners learn instead depends on several factors including the approaches and strategies that the teachers use to engage the content (Dohn 2016:188). Van Aalderen-Smeets et al. (2017:239) found that learners' attitudes towards science and their learning goals in science were strongly influenced by their teachers' own attitudes. It has therefore become important that in order to determine ways of changing the learners' attitudes towards natural sciences in the context of the STEAM educational approach, the following questions and sub-questions need to be answered by the researcher:

1. Can the application of puppetry art as a teaching tool to teach ecology within the context of the STEAM educational approach influence learners' attitude to change towards natural sciences? From the first main research question, the following sub-questions are identified:
    1.1 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' personal interest category of their attitudes towards the subject?
    1.2 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' conceptual and applied conceptual understanding categories of their attitudes towards natural sciences?
    1.3 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' sense-making effort category of their attitudes towards natural sciences?
    1.4 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' general problem-solving confidence and sophistication categories of their attitudes towards natural sciences?
    1.5 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' real-world connection category of their attitudes towards natural sciences?

2 Can a guideline for the integration of puppetry art as a teaching tool in natural sciences be effectively applied within the context of the STEAM educational approach?

Hypothesis

The application of puppetry art as a teaching tool can influence learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication as well as real-world connection categories regarding their attitude towards natural sciences.

The null hypothesis

The application of puppetry art as a teaching tool to teach ecology has no influence on learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication and real-world connection categories regarding their attitude towards natural sciences.

1.6 Research objectives

In view of the above-mentioned research questions, this study aims to achieve the following objectives which are aligned to the research questions:

1.6.1 To determine if the application of puppetry art as a teaching tool will influence the learners' personal interest category of their attitudes towards the subject.

1.6.2 To determine if the application of puppetry art as a teaching tool will influence the learners' conceptual and applied conceptual understanding categories of their attitudes towards the subject.

1.6.3 To determine if the application of puppetry art as a teaching tool will influence the learners' sense-making effort category of their attitudes towards the subject.

1.6.4 To determine if the application of puppetry art as a teaching tool will influence the learners' general problem-solving confidence and sophistication categories of their attitudes towards natural sciences.

1.6.5 To determine if the application of puppetry art as a teaching tool will influence the learners' real-world connection category of their attitudes towards the subject.

1.6.6 To develop and formulate recommendations and/or guidelines for the effective application of puppetry art as a teaching tool in natural sciences within the context of the STEAM educational approach.

1.7 Research design and methodology

The quantitative experimental research design was employed in this study. Simple random sampling, a type of probability sampling was used to select the participants. The reason for the choice of this technique was that every individual in the sampling frame (i.e. desired population) had an equal and independent chance of being selected for the study (Onwuegbuzie & Collins 2007:285).

The other reason for the choice of the quantitative experimental research design was that it allowed the researcher to have control over the experiment, and randomly assign subjects/participants to the experimental and control groups. Having control and randomisation strengthened the internal validity of the study (Kraska 2010:4). Randomisation was also used to establish a cause-and-effect relationship between the use of puppetry art as a teaching tool and a possible attitude change of learners towards natural sciences (Kraska 2010:5).

The quantitative research methodology relied on the collection and analysis of numerical data in the study of social phenomena (Leung & Shek 2018:2). Embedded in the paradigm of positivism and post positivism, the quantitative research methodology emphasises empirical inquiry to understand social phenomena. This research methodology advocates the demonstration of internal validity (accurate interpretability of the research findings), external validity (generalisability of the research findings) and reliability (consistency and replicability of the findings) (Leung & Shek 2018:3).

The research methodology also has its roots in the logical positivist philosophy of science (Miller 2011:2). This is marked by operationalism (the belief that all theoretical terms can be reduced to observable phenomena). It also encompasses the belief that a totally unbiased account of the world can be achieved through the careful application of the scientific method (Miller 2011:2).

The ontological and epistemological foundations that underpin the quantitative research methodology suggests a clear direction for judging the quality of the research effort. This includes how well the research was conducted, which distinguishes unbiased, open, honest, and precise research from that which is not (Smith 1990:172). The technical merits of functional research are typically assessed with standards of validity and reliability (Miller 2011:5).

The experimental research design was more representative than other types of design. In general, it avoided researcher bias in the selection of participants for the study, it permitted estimates of sampling error and it also enabled the researcher to estimate the accuracy and representativeness of the participants selected for the study (Babbie 2010:198). The experimental research design incorporated experimental and control groups. The comparison of the experimental group and the control group at the end of the study indicated the effect of the experimental stimulus (puppetry art as a teaching tool, in the case of this study).

The classic experimental and control group design was employed in this study. It incorporated the pre-test and post-test control group design (Kothari 2004:42; Mujis 2011:16). In this type of design, the subjects were placed into two groups, the experimental and control groups. The experimental groups were administered with the experimental intervention stimulus (i.e. they were taught balance in the ecosystem, conservation of the ecosystem and feeding relationships in Ecology (see appendix I) with the aid of puppetry art, in this study), while the control groups were taught the same content in Ecology without the use of puppetry art, using textbooks and curriculum materials. The null hypothesis is the assumption about the relationship between the dependent and the independent variables. It assumes that there is no relationship between the dependent (the possible attitude change of learners towards natural sciences) and the independent variables (the application of puppetry art as a teaching tool) (Bloomfield & Fisher 2019:27). Therefore, by drawing a sample from a known population of Grade 9 learners, measuring the variables and testing them using the analysis of covariance, the null hypothesis can either be accepted or rejected, based on the outcome of the statistical analysis (Bloomfield & Fisher 2019:27).
Both groups were similar in composition except for the administration of the experimental stimulus. Both groups underwent a pre-test, which was used to

measure their attitudes before the intervention (experimental stimulus), and a post-test on the same instrument after the intervention was given to the experimental group.

The Colorado Learning Attitudes about Science Survey (CLASS) questionnaire was administered to the participants as a pre- and post–test attitude survey (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman 2006:1) to both the experimental and control groups of the participants. Following the post-test, descriptive statistics was applied to statistically determine if there were any effects as a result of the experimental stimulus (Mujis 2011:16), which was the use of puppetry art to teach balance in the ecosystem, conservation of the ecosystem and feeding relationships. This was done by comparing the change in the dependent variable in the control group with the change in the dependent variable in the experimental group. If the post-test indicated that the overall level of attitude change towards natural sciences exhibited by the experimental group increased after the administration of the experimental stimulus, this indicated that the intervention might have been responsible (Babbie 2010:233).

Table 1.1 below shows a summary of the research design. It shows that the experimental stimulus was administered to the experimental group during the data collection exercise, while the control group did not receive any experimental stimulus. This type of design is superior to other types of experimental and control group designs because it avoids extraneous variation resulting from both the passage of time and from the non-compatibility of the experimental and control groups (Kothari 2004:42; Leung & Shek 2018:3).

Groups	**Pre-test**	**Treatment**	**Post-test**
Experimental	YES	YES	YES
Control	YES	NO	YES

Table 1.1 The summary of the quantitative experimental design (Mujis 2011:6)

1.8 Data collection

The CLASS pre- and post–attitude survey (Adams et al. 2006:1) was used to collect data for the study. The reason for the choice of the CLASS attitude survey, was that, according to Adams et al. (2006:1), the CLASS is an instrument designed to measure learners' attitudes about science and about learning science. This instrument extended previous work by probing additional aspects of learners' attitudes and beliefs by using wording suitable for learners in a wide variety of science classes. The CLASS has been validated using interviews, reliability studies, and extensive statistical analyses of responses from over 5000 students (Adams et al. 2006:5). This survey was conducted to determine the effectiveness or otherwise of the use of puppetry as a teaching tool for attitude change in natural sciences.

The pre- and post-test attitude measurement instrument included a set of 43 statements that described the attitudes of learners towards learning natural sciences. These statements were grouped into the following categories: (a) real world connection, (b) personal interest, (c) sense-making/effort, (d) conceptual connections, (d) applied conceptual understanding, (e) problem solving, general, (f) problem solving confidence, (g) problem solving sophistication, (h) not scored (Adams et al. 2006:13). This was administered to both the experimental and control groups at the beginning and at the end of the study. The groups were asked to rate each statement by circling a number between 1 and 5 in a Likert scale where the numbers indicated the following: 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree (Madsen, McKagan & Sayre 2015:1).

The pre- and post-test attitude survey responses for both the experimental and control groups were compared and analysed statistically using descriptive statistics (total, mean, median, standard deviation, minimum, maximum) to determine if there were any attitude change due to the exposure of the experimental groups to the use of puppetry as a teaching tool. The pre-test attitude survey was used to assess learners' attitudes towards natural sciences before the use of puppetry as a teaching tool within the experimental groups. The post–test attitude survey was used to determine if there were any changes in the learners' attitudes towards natural sciences after the use of puppetry as a teaching tool.

1.8.1 Selection of participants

The participants were the individuals who were selected to participate in the research study. They were the major units of analysis in the quantitative study and were selected using simple random sampling techniques (Persaud 2010:2). Probability sampling involved selecting samples in accordance with probability theory, and this included a random selection mechanism (Babbie 2010:196). Simple random sampling ensured that no systematic bias occurred during the selection process (Persaud 2010:2).

The reason for the choice of simple random sampling was that every individual in the sampling frame (i.e. desired population) had an equal and independent chance of being selected for the study (Onwuegbuzie & Collins 2007:285). It was more representative than other types of sampling, it avoided researcher bias in the selection of learners for the study, it permitted estimates of sampling error and also enabled the researcher to estimate the accuracy and representativeness of the learners selected for the study (Babbie 2010:198).

The participants consisted of 355 Grade 9 natural sciences learners from three selected schools designated Schools A, B and C in the Motheo District of the Free State. There were 120 Grade 9 learners from each of the three participating schools. These learners were similar with respect to gender, grade and age. This ensured that individual learners were similar in specific characteristics, so as to control for extraneous variables (Onwuegbuzie & Collins 2007:286). According to Babbie (2010:199), a study population is the group that the researcher is interested in generalising about.

In each of the participating schools, the experimental and control groups were randomly selected from all the Grade 9 classes. They had an equal number of male and female learners. The experimental groups were taught balance in the ecosystem, conservation of the ecosystem and feeding relationships in Ecology (see appendix I) using puppetry art as a teaching tool, while the control groups were taught the same topics in Ecology using the traditional method of textbooks and curriculum materials. The pre-test (before the administration of the experimental stimulus to the experimental group) and post-test were administered to both the experimental and control groups (Mujis 2011:6).

Figure 1.2 below shows the random assignment of learners from the selected schools into the experimental and control groups. In each school, there were a proposed number of 60 Grade 9 learners in the experimental group and 60 Grade 9 learners in the control group, making a total of 120 learners. The total number of learners that participated from the three different schools in the study added up to 355 learners in both the experimental and the control groups.

The participant selection for the study, adapted and modified from Drew, Hardman and Hosp (2014:8), is as follows

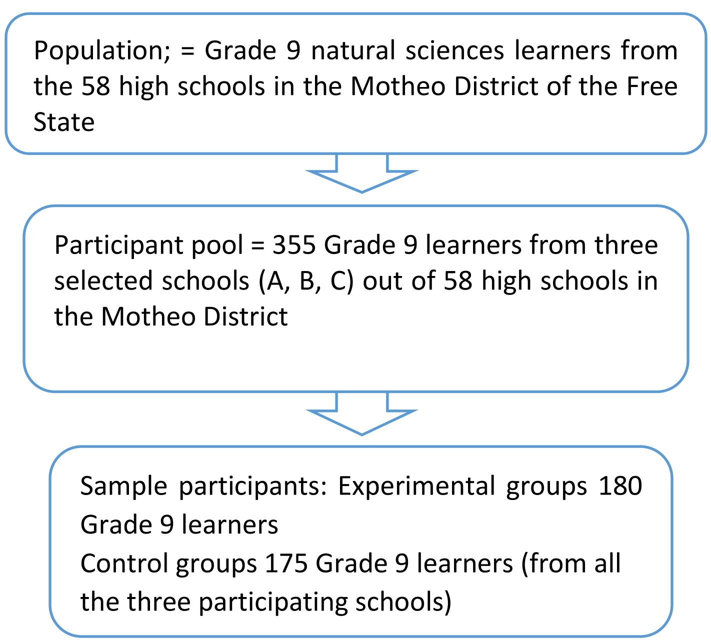

Figure 1.2 The participant selection for the study (Drew et al. 2014:8)

1.8.2 Data analysis

The data obtained was analysed quantitatively using descriptive statistics. According to Babbie (2010:445), quantitative data analysis involves techniques that convert data into numerical forms that are then analysed statistically. It allowed the researcher to make descriptive inferences about the larger population. The software that was employed for data analysis was the SAS Institute Incorporated SAS/STAT 13.1, which was developed by the SAS Institute in Cary, North Carolina.

The pre- and post-attitude survey responses from the learners were matched to determine that the shifts in attitudes being calculated were the differences in the learners' thinking, and not a difference in the number of learners who took the survey. The pre- and the post-attitude survey responses from the 355 Grade 9 learners were compared to the answers given by experts on the same 43 questions according to the CLASS Expert Response Key (see appendix B) before statistical analysis. This was done to determine the percentage favourable score.

The next step was to calculate the percentage favourable score from the pre- to the post-attitude survey. Individual questions were scored as 1 if the participant learner responded with "strongly agree" or "agree" for 'A' class questions (those statements with which experts "strongly agree" or "agree"), otherwise the score will be 0. Similarly, individual questions were scored as 1 if the participant learner responded with "strongly disagree" or "disagree" for 'D' class questions (those statements with which experts "strongly disagree" or "disagree"), otherwise the score was 0.

For each learner, the average number of questions (out of 43) that they answered in the same way as an expert were determined. This represented the "percentage favourable score". The "percentage unfavourable score" was the number of questions the learners did not answer in the same way as an expert. "Neutrals" were scored as neither agree nor disagree with the expert. If the learners left questions blank, the average percentage favourable score was calculated out of the number of questions that they answered (Adams et al. 2006:3). The learners' individual average percentage favourable scores were then averaged to find the class average percentage favourable score.

This process was repeated to find the class average percentage unfavourable score, which was the number of questions the learners did not answer in the same way as an expert (Adams et al. 2006:2). The Total Mean and Standard deviation, and Minimum, Median and Maximum were calculated for the above mean scores by study period (pre- and post-test) and by group (experimental and control). Furthermore, these descriptive statistics were also calculated by school (A, B, C), study period (pre- and post-test), and by group (experimental and control) (Leung & Shek 2018:7). The analysis of covariance (ANCOVA) was later used to compare the outcomes of the analysis between the experimental and control groups.

Analysis of covariance (ANCOVA) was a statistical control procedure that was used in the study design to remove the effect of one or more confounding variables. It reduced unexplained outcome variance, thereby increasing the power of the treatment test effect and reducing the width of its confidence interval (Van Breukelen 2012:2). It served to increase the sensitivity of the statistical test of the experimental factor in the statistical model (Sim 2018:2).

Regarding each questionnaire category/domain, the experimental group was compared to the control group using analysis of covariance (ANCOVA) with the mean score (post) of a domain as dependent variable, and the following independent variables:

•School (three categories)

•Group (two categories - experimental vs control)

•The corresponding mean score (pre) as covariate

From these ANCOVA, the least squares post-intervention mean scores for each group (experimental and control) were calculated, as well as the "experimental –

control" difference in mean scores, the 95% confidence interval for the mean difference, and the P-value for the test of the null hypothesis that the mean difference is 0 (that is, null hypothesis of no difference between experimental and control groups) regarding the research questions.

The results were presented in the form of tables. From these distributions the Total, Mean and Standard deviation, and Minimum, Maximum and Median were calculated. The assumption therefore was that, if there was any significant change in the shape of the distributions from before the use of puppets as a teaching tool, to after the use of puppets as a teaching tool, with respect to the learners' attitudes, then the stimulus was in part responsible for the change in attitudes (Pretorius & Von Maltitz 2010:129) as there were other factors that might influence attitudes.

1.9 Value of the research

Research in education is aimed at solving problems in education. Educational research is an area of enquiry which involves taking a careful look at the educational situation and problems of human society, and searches for solutions (Etudor-Eyo, Emah, Etuk and Archibong, 2011:917). In view of this, the research aims to determine the problem of learner attitudes towards science, and the possible use of puppetry art as a teaching tool to change their attitudes in the context of STEAM education.

This research, therefore, aims to contribute to the body of existing knowledge in curriculum studies on ways to improve learners' attitudes towards the teaching and learning of natural sciences, using puppetry art as a teaching tool. On an epistemological level, this study will result in design principles that science teachers could utilise to implement the use of puppetry art as a teaching tool in the science classroom. The study will also make a methodological contribution towards the validation of the application of puppetry art as a teaching tool in changing learners' attitudes towards natural sciences in the classroom.

1.10 Ethical considerations

The approval of the research unit of the Free State Department of Basic Education was sought and obtained before the commencement of the data collection process. Research ethics can be grouped into the following categories: (a) guidelines and oversight (Herrera 2012:2), (b) autonomy and informed consent (Alferes 2013:16), (c) standards and relativism, (d) conflict of interest, and (e) the art of ethical judgement (Persaud 2010:3). All these were aimed at the common theme of ethical consideration, which was that the prerogatives of the study will be secondary to the dignity and overall welfare of the participants (Herrera 2012:3; Alferes 2013:17). Ethics in a research project emphasises the need to protect the interests of the participants in the research process without compromising the standards of the research (Tangen, 2014:678).

The participants' privacy must be protected in quantitative data analysis and reporting (Babbie, 2010:446). In view of this, permission was sought from the University of the Free State through its ethical processes and procedures, the principals of the schools where the research was conducted, as well as the parents/guardians of the prospective participants in the study through informed consent letters that sought their consent for the participation of their wards.

The parents/guardians of the learners who participated this project were issued with assent letters in addition to informed consent letters. The details of the research were outlined in the letters, and the possible consequence of participation was clearly highlighted. Although no ethical issues were anticipated during this research, action was taken to follow all the necessary steps

1.11 Layout of chapters

This research consists of the following chapters:

CHAPTER ONE. This chapter is introductory. It focused on the background to the study, the problem statement, the research questions, hypothesis as well as the objectives for the study, and a brief overview of the research design and methodology. The conceptual and theoretical framework for the study – Ajzen's theory of planned behaviour as well as the Cultural Historical Activity Theory (CHAT) were highlighted. The ethical considerations that was followed during the study was also discussed, and also the value of the research.

In CHAPTER TWO, a review of the relevant literature was done to gain insight into the numerous research studies conducted by various scholars regarding the STEM and STEAM educational approaches. This was done to establish why the STEAM approach is a better option for the integration of puppetry art as a teaching tool. The application of puppetry art in education was extensively discussed and the theoretical lens of the cultural historical activity theory CHAT was applied to view the STEAM-puppetry art integration as a teaching tool for attitude change in natural sciences.

CHAPTER THREE is another theoretical chapter in which the researcher reviewed relevant literature on the attitudes of learners towards natural sciences. The conceptual framework for the study, Ajzen's theory of planned behaviour, was discussed and applied to the context of the study, to buttress the theoretical argument for the integration of puppetry art as a teaching tool for attitude change in natural sciences within the context of the STEAM educational approach.

CHAPTER FOUR focused on the research design and methodology. A detailed description of the quantitative experimental research design, including its epistemology and ontology as well as why it was employed in the research project, was addressed. The sampling methods employed in the selection of the participants as well as the study population were also discussed. The Colorado Learning Attitudes about Science Survey (CLASS) attitude survey, the data collection instrument, was described in detail, as well as the rationale for the choice of this specific instrument. A brief overview of the data analysis process was discussed, as well as the ethical issues involved in academic research, and how these were mitigated during data collection.

In CHAPTER FIVE the details of the results of the analysed data obtained during the study were presented. Descriptive statistics for the individual questions in the attitude survey was analysed. These included the categories of personal interest, real-world connection, problem solving – general, problem-solving confidence, problem solving sophistication, sense-making effort, conceptual understanding as well as applied conceptual understanding categories of learners' attitudes were analysed and summarised in tables. The test of the null hypotheses on the application of puppetry art as a teaching tool were also analysed, compared and presented in tables.

CHAPTER SIX focused on the discussion of the results. The various categories of the results obtained were fully discussed in this chapter. An evaluation of the implications of the application of puppetry art as a teaching tool were made as well as the discussion of the limitations of the study.

CHAPTER SEVEN discussed the summary of findings, the conclusion, and the recommendations for further study. The detailed discussion of the findings of the study regarding the main research question, sub-questions and the respective linked objectives were done. A revisit of the data analysis procedure was made, as well as recommendations and suggestions for further study. The list of scholarly reviewed articles employed during this study was stated in the REFERENCES.

CHAPTER TWO

LITERATURE REVIEW OF THE STEM vs STEAM EDUCATIONAL APPROACH AND THE THEORETICAL LENS

2.1 Introduction

"Overemphasis on rote learning and rigid, dogmatic adherence to rules of discipline are not only deterrents to learners… they are fundamentally incompatible with the true nature of science" (Schmidt 2011:441). This statement argues that learners' negative attitudes and declining interest in science may be attributed to a fundamental flaw in the teaching approaches and tools employed in the teaching and learning of the subject. These approaches, according to the statement of the scholar, tend to constrain the learners and limit their creative potential and excellence in science. Furthermore, they do not reflect how science should be taught. To further highlight the shortcomings of traditional teaching approaches, the scholar adduces that "traditional models of teaching and learning science have done much to cultivate perceptions of science as a non-creative endeavour" (Schmidt 2011:411).

The above statement illustrates the shortcomings of traditional teaching methods and approaches in the teaching and learning of science. For instance, one needs creativity and imagination to form mental images of entities such as electrons or atoms, as they are invisible to the eye (Turkka, Haatainen & Aksela 2017:1403). This necessitates the need for the adoption of a pragmatic approach to teaching, which will make it fun and attractive for learners to learn science. Understanding that creativity can exist in science supports the idea that science can be taught in multiple ways. This will enable learners to see the overlap in practices between art and science (Tsurusaki, Tzou, Conner & Guthrie 2017:269).

There are two main approaches that aim at effective science teaching and learning. They are the STEM (Science, Technology, Engineering and Mathematics) educational approach and the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. The STEM educational approach aims at motivating learners through practices, contexts and processes that will enable them to participate in science activities that will lead to STEM career pathways (Connors-Kellgren, Parker, Blustein & Barnett 2016:825; Ring, Dare, Crotty & Roehrig 2017:444). It employs an interdisciplinary approach to problem solving and equips the learners with 21st century skills, as well as the opportunities to apply these skills (Vennix, Den Brok & Taconis 2018:1264) through the provision of hands-on activities targeted at understanding science and the ability to view science differently (Vennix et al. 2018:1265).

According to Kim and Kim (2016:1910), effective teaching competency is critical, and so is the quality of the teachers. It is therefore suggested that teaching science through approaches that connect STEM and the art disciplines, the STEAM approach will illustrate and expose the learners to the creativity of science by highlighting its overlap with the arts (Tsurusaki et al. 2017:270). In order to enhance science teaching and learning, the integration of the arts into STEM lessons becomes important. The STEAM educational approach employs a transdisciplinary approach to problem solving. This has the potential to engage the learners more deeply (Cook, Bush & Cox 2017:86), because creativity and imagination are required in science to visualise and express abstract concepts (Turkka et al. 2017:1403).

One explanation regarding increased motivation with the integration of the arts into science teaching is the fact that the arts enable multiple ways to express and explore the scientific content (Turkka et al. 2017:1407). The STEAM approach, therefore, will enable learners to engage the science content through the arts (Tsurusaki et al. 2017:270). The integration of the arts into STEM fields has been found to increase learners' science efficacy and creativity, and to maximise their interest and motivation in science. This in turn helps to improve their competitiveness (Kim & Chae 2016:1927). The STEAM educational approach, therefore, encourages learners to take the initiative in their learning (Kim & Kim 2016:1921). This implies that it encourages learners to solve challenging problems themselves, which increases their science learning efficacy (Kim & Kim 2016:1912), as well as their confidence (Kim & Chae 2016:1928). It has therefore, become necessary to enhance learners' active learning through the creation of an open learning atmosphere, where learners can interact with the content being taught using art as a teaching tool.

Perception plays a key role during an activity, and what is perceived is influenced by the teacher's instructions and previous experiences, and the knowledge of the learners. Therefore, the perceptions regarding educational objects can be very different in science and arts (Turkka et al. 2017:1405). For instance, observing a pot of melting snow, could be perceived as the transformation from solid to liquid in science, or the transformation from the visible to the transparent in the arts (Turkka et al. 2017:1405). But both science and arts require observation.

The arts will enable inspiration and novelty as well as the development of cognitive and social growth. It will also enhance creativity, reduce stress, and make science teaching enjoyable (Sousa & Pilecki 2013:29). The arts have been used in the school system for a long time, especially in primary schools where materials such as clay, wood, gold and silver were used for the purpose of enrichment (Najami, Hugerat, Khalil & Hofstein 2019:97). According to Najami et al. (2019:98), drama-based pedagogy focuses on process-oriented and reflective experiences and draws on a broad range of applied theatrical strategies which can develop learners' creativity, abilities and aesthetic awareness.

The learning of science is the process of acquiring scientific skills, knowledge, and values. The development of positive learner attitudes towards science may well depend on the approaches or strategies or tools that teachers use to engage with the content (Blackman et al. 2012:160). The use of the arts, therefore, is crucial because it will enable learners to develop creative thinking and scientific communication skills, as well as addressing their affective learning outcomes (De Beer et al. 2018:3).

In the next section, the STEM educational approach will be compared to the STEAM educational approach in order to support the argument in favour of the STEM to STEAM shift for the effective teaching and learning of science.

2.2 Comparing the STEM to STEAM educational approach

In this section the researcher will critically examine existing literature on the STEM (Science, Technology, Engineering and Mathematics) educational approach and STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach to elucidate why STEM education needs to become STEAM.

2.2.1 The STEM educational approach

STEM is an acronym for Science, Technology, Engineering, and Mathematics. It employs an interdisciplinary approach to education that focuses on authentic learning processes. This requires inquiry, imagination, questioning, problem solving, creativity, invention, and collaboration (Myers & Berkowicz 2015:10). It emphasises the importance of 21st century skills such as critical thinking, agility, initiative, effective communication, and morals. It also supports accessing and analysing information, as well as opportunities to apply learned information and concepts in the field of science (Vennix et al. 2018:1264).

The STEM educational approach is anticipated to prepare learners to acquire thinking abilities which will enable them to become creative and analytical thinkers (Aldahmash, Alamri & Aljallal 2019:2). According to Aldahmash et al. (2019:3), the goal of an integrated STEM curriculum is to increase learners' acquisition of knowledge and provide society with highly qualified scientists, technologists, engineers and mathematicians, which is crucial in the 21st century.

The STEM educational approach is also anticipated to provide opportunities for learners to experience and engage in real world problems. This is because problem-solving is central to the four disciplines of STEM, i.e. Science, Technology, Engineering and Mathematics (Vennix et al. 2018:1267).

Research shows that the STEM educational approach has fallen short of its expectations, as there is still a shortage of STEM graduates and professionals (Hillman, Zeeman, Tilburg & List 2016:204). Moreover, the number of learners choosing STEM careers is declining, in a time that the demand for people to fill scientific positions is rapidly increasing (Hillman et al. 2016:203). The poor performance of learners from the USA in science and mathematics is also a concern that points to the need for improved STEM education (Rogers & Sun 2019:1).

The failure of the STEM educational approach to provide the solution to improved learner performance in science, coupled with the overall learner underperformance, is a cause for concern. This is indicative of a system that is failing to equip the learners with the necessary knowledge and skills needed for success (National Academy for Science 2012: online; Rogers & Sun 2019:3) in the 21st century. These failures may be attributed to a lot of factors including the teacher-centeredness of the STEM educational approach, with knowledge and assessment-centred environments instead of learner-centeredness. This contrasts with key STEM skills of collaboration, communication and problem-solving (Rogers & Sun 2019:3).

Herro and Quigley (2017:418) adduce that the STEM educational approach has not provided the much-needed knowledge to equip learners with the necessary skills and attitudes needed to spur critical thinking in the learning of science. This failure can be attributed to the focus that STEM education places on mathematics and science. They further argue that it is not content-based and not really aligned with real-world situations.

The most prolific challenge to STEM education, presently, is to overcome the barriers that inhibit learners from succeeding in the STEM curriculum (Rogers & Sun 2019:14). The solution to this problem may lie in learning through the true blending of disciplines. This might offer the learners the opportunity to solve problems set in a real-world context. They might learn new concepts from the different disciplines, especially the arts, in order to develop positive attitudes and reach a viable solution (Bush & Cook 2019:21).

In the next section, the researcher will critically examine the existing literature on a teaching approach that engage with scientific ideas through art called the STEAM educational approach.

2.2.2 The STEAM educational approach

STEAM is an acronym for Science, Technology, Engineering, Arts and Mathematics. The difference between STEM and STEAM lies in the inclusion of the 'Arts' into STEAM. It employs a transdisciplinary approach to develop multiple perspectives that inform deliberation on a problem. A transdisciplinary approach begins with the problem, and through the process of problem-solving brings to bear the knowledge of those disciplines that contributes to a solution (Meeth 1978:10). This approach also employs the collective expertise from many disciplines to pose and solve problems and does not focus on individual disciplines (Quigley & Herro 2016:412). According to Herro and Quigley (2017:419), the STEAM educational approach incorporates a transdisciplinary approach to learning science, which allows learners to learn and solve real-world problems. The adoption of a transdisciplinary approach ensures that the learners learn through a blend of disciplines, because the arts creates creativity (Bush & Cook 2019:21).

The STEAM approach incorporates the application of theories, concepts or methods across disciplines, with the intent of holistically developing the learners (Lattuca 2001:83), and to foster thoughtful reflections on their creative processes (Guyotte, Sochacka, Constantino, Kellam & Walther 2015:30). It utilises project-based learning as a vehicle for learning scientific concepts (Opperman 2016:1) to expand the model of education from STEM to STEAM. It also incorporates teaching methods that build authentic higher order thinking and creative problem-solving abilities in the learners (Kim & Kim 2016:1912).

The STEAM educational approach incorporates the arts to enhance science education through exposing the learners to the objective view offered by science as a compliment to the subjective view of the world as espoused by the arts (Sousa & Pilecki 2013:10; Kim & Chae 2016:1928). The arts may help learners to draw on curiosity, observe accurately, think spatially, perceive aesthetically and work effectively with others (Sousa & Pilecki 2013:11). It has been found to increase the scientific efficacy and creativity of learners. It also maximises their interest and motivation in science, which helps to improve their scientific competitiveness (Kim & Chae 2016:1927). This might contribute to a positive attitude towards science.

The framework for the STEAM educational approach incorporates the common processes of science and arts. These include discovery, observation, experimentation, description, interpretation, analysis, evaluation, observing, wondering, visualising, exploring and communication, although there are differences in the manifestation of the processes in each of the fields (Fulton & Simpson-Steele 2016:2). These differences can be linked to the emphasis which the arts place on combining knowledge and personal experience, while science focuses primarily on the search for objective evidence to generate knowledge (Conner, Tzou, Tsurusaki, Guthrie, Pompea & Teal-Sullivan 2017:2224).

The aim of the STEAM educational approach is the application of arts to improve on learners’ confidence, attitudes, and interest in science (Kim & Chae 2016:1926) through new approaches to solving problems. The goal of this transdisciplinary approach is aimed at powerful, authentic learning opportunities, which can help the learners to tackle challenging STEM fields needed in the future workforce (Jamil et al. 2017:1).

This is mainly because the STEAM educational approach is learner-centred as opposed to teacher-centred, which enables learners to see themselves as designers and creators (Cook et al. 2017:86). It encourages learners to discover how to create new things, see familiar things in a new way, combine things in non-traditional ways and think independently and unconventionally (Jamil et al. 2017:2).

This approach, therefore, focuses predominantly on how to leverage the arts to provide a range of benefits to STEM learners (Guyotte et al. 2015:1). It also recognises the power of the arts in engaging more diverse types of learners (Bush & Cook 2019:20). This is possible because it draws on curiosity, the ability to observe accurately, perceive an object in a different form, and construct meaning (Sousa & Pilecki 2013:11). This leads to expressing observations more accurately and working effectively with others (Herro & Quigley 2017:420; Bush & Cook 2019:21).

Participating in arts-mediated science learning has been associated with a wide variety of positive outcomes, such as improved long-term memory (Sousa & Pilecki 2013:20, 23). It also enables learners to understand the importance of human connections and the expression of feelings, which influence attitude changes (Rothkopf 2016:63). The integration of the arts in science lessons, therefore, has the potential to engage the learners more deeply (Cook et al. 2017:86) and influence their attitudes towards science.

The arts remain a medium for ideation or the conceptualisation, study, and exchange of ideas (Keane & Keane 2017:64). The arts are a collection of skills and thought processes that transcend all areas of human endeavour (Sousa & Pilecki 2013:17). It provides learners with opportunities to develop unique ways of knowing and interpreting the world (Keane & Keane 2017:63). The arts also elucidate empathy, and this can be a powerful tool in helping to build learners' motivation and passion towards solving problems in science (Bush & Cook 2019:32). The use of the arts in the teaching and learning of science adds an affective component to the complex STEM concepts and problems. This makes the learning of contents in science more accessible (Smith & Paré 2016:212) and more engaging (Bush & Cook 2019:20), and it could reinforce learners' positive attitudes towards science. The STEAM educational approach therefore aims at the transformation of natural science teaching and learning to inform creativity (Fulton & Simpson-Steele 2016:10-11), which may influence the attitudes of learners by practically minimising the barrier to knowledge (Marmon 2019:105).

In the next section, the researcher will argue, within the confines of existing literature, why there should be a shift from a STEM to a STEAM approach, in order to curtail the declining interest and attitudes of learners about science.

2.2.3 The significance of the STEM to STEAM shift

The framework for the STEAM educational approach comprises problem-solving and creativity, which encourages learners to look for ways of solving problems on their own (Kim & Kim 2016:1911). The aim is to develop learners' creativity through the convergence of the arts and science, based on the idea of improving learners' interest in science through holistic arts education (Kim & Chae 2016:1910).

The STEAM educational approach highlights creativity, an emotional touch and the convergence between the arts and science disciplines (Park, Byun, Sim, Han & Baek 2016:1742). This will enable learners to experience immense satisfaction of solving a challenging problem on their own, thereby increasing their confidence (Kim & Chae 2016:1928). This is because both the sciences and the arts require discovery, observation, experimentation, description, interpretation, analysis, and evaluation (Fulton & Simpson-Steele 2016:2).

According to Kim and Chae (2016:1925), recent developments in science and technology has led to an increase in globalisation, convergence, and unpredictability, causing the need to arise for future scientists to develop creative problem-solving skills and global expertise rooted in arts education. This has become necessary because STEM's focus on education based on science or mathematics is not enough.

The inclusion of the 'A'rts in STEM activities delivers a natural platform for trans-disciplinary inquiry (Quigley & Herro 2016:410) which will have a positive effect on learners' attitudes towards learning science (Yuksekyalcin et al. 2016:220). The STEM to STEAM shift emphasises the relevance of the arts and creativity within the traditional STEM fields of Science, Technology, Engineering and Mathematics (Marmon 2019:103). Studies have found that creativity influences learners to higher levels of thought and the ability to navigate difficult and stressful situations (Marmon 2019:106), because critical thinking facilitates the innovation required to solve problems (ibid.). This might improve their attitudes towards science.

The transdisciplinary approach of STEAM provides multiple approaches to solving a problem, which may promote learners' positive attitudes towards science (Bush & Cook 2019:33) and offer flexibility and peace of mind. The STEAM educational approach also advocates collaborative learning. This might enable the learners to synthesise ideas and work with one another to solve problems. It therefore complements the goals for 21st century learning, which focuses on problem-solving through innovation, design, and creative thinking (Bush & Cook 2019:33).

The purpose of the STEAM educational approach, therefore, is to apply the arts in the teaching and learning of science, in order to deepen the learning rather than teaching the arts (Romagnoli 2017:25), since applied knowledge leads to deeper learning. The shift from STEM to STEAM lays emphasis on the development of critical thinking, creativity, and communication, which are critical skills needed in the integration of knowledge across disciplines (Bazler & Van Sickle 2017: xix). It also focuses on the individualisation of learning, which enables learners to explore their strengths, and utilise these strengths in the development and consolidation of the studied content, thereby consolidating their positive attitudes (Bazler & Van Sickle 2017:xxi) towards science.

According to Ramagnoli (2017:35), the application of the arts in science teaching may also help learners to look beyond scientific concepts as merely equations, proofs, memorised operations and prime numbers, but rather as people whose experiences affect science and mathematics. For instance, the scientific concept of force and motion (STEM) can be taught using human movements i.e. dance (STEAM). This deepens and situates the learning and helps the learners to consolidate their understanding of the theory, concepts and skills (Lindquist et al. 2017:110).

Cook et al. (2017:86) also emphasised the importance of the integration of the arts in science lessons, since it has the potential to engage the learners more deeply. The STEAM educational approach, therefore, is learner-centred rather than focusing on the subject area (Tsurusaki et al. 2017:255). The shift from STEM to STEAM, therefore, is not only expressed in the addition of the 'A' to STEM, but also in the recognition that aesthetics, beauty and emotion (affect) play important roles in problem-solving (Marmon 2019:103). This highlights the importance of the arts as a solution to the complex STEM concepts and problems, and also as a foundation for perpetuating innovation in the future (Mehta, Keenan, Henriksen & Mishra 2019:118).

STEAM education represents the future of innovation and creativity. Csikszentmihalyi (1997:28) defines creativity as an act or idea that changes an existing domain or that transforms an existing domain into a new one, and a creative learner as a person whose thoughts or actions change a domain or establish a new domain. Art and science share many overlaps in terms of both common practices and habits of mind, which can be harnessed in transdisciplinary thinking to enhance creativity (Tsurusaki et al. 2017:256). STEAM education as an approach, therefore, employs the arts, which embodies creativity, to connect disciplines that were previously perceived as disparate, and provide learners with the necessary skills, problem-solving and positive attitudes needed to excel in the field of science (Marmon 2019:112-113) in the 21st century.

From the literature reviewed on the importance of the incorporation of the arts (STEAM) in the teaching and learning of science, it can be deduced that it will provide learners with the benefits of the above-mentioned advantages to enhance their creativity and positive attitudes towards the subject. I shall now use a specific example to illuminate the ideas in this section further.

2.3 The application of puppetry art in education

The use of drama (art) in the teaching of science will help learners to view science as a human-social experience, which might enhance their understanding of the world rooted in scientific and humanistic traditions. This draws them closer to science and increases their positive attitude towards science. The power of drama in combining the elements of art, music and sport can also help learners to develop creativity as well as an affective and aesthetic awareness (Najami et al. 2019:98).

As Braund et al. (2013:5) point out, the arts are one of the traditions amongst socio-cultural and socio-linguistic traditions that can lead to active teaching and learning in science. According to research, learners learn best through active participation and interaction with the teacher and other learners in the learning process (Chi & Wylie 2014:219). Active participation means that the learners are cognitively and meaningfully engaged with the learning content (Pino-Pasternak & Volet 2018:1523).

Since the arts is used to express feelings and ideas (Turkka et al. 2017:1407), it is not surprising that methods drawn from the arts have been suggested when dealing with controversial issues in science education. This is because the arts enable multiple ways of expression and exploration of the science content (Turkka et al. 2017:1408).

Arts education is primarily focused on creativity and is an essential component of innovation (Marmon 2019:102), which promotes problem-solving and makes learning natural science fun and attractive. Research has shown that instructional methods embedded in arts education have yielded more motivated and engaged learners who can increase their learning (Mishra & Henriksen 2013:4; Marmon 2019:105). Puppetry art provides a platform for the presentation of natural science lessons that lead to effective and meaningful construction and application of knowledge (Marmon 2019:104).

Puppets can be described as visual and symbolic representations that can communicate ideas in a sophisticated manner, and act as a communication medium (Kruger 2007:72). Puppets are powerful and stimulating tools in educational entertainment and have been used extensively in educational entertainment in South Africa for many years (Kruger 2008:38). Puppets, therefore, are theatrical creatures that exist, and are autonomous art forms that derive philosophical principles from performances and seek meaning in materiality (Cohen 2017:275).

Puppetry art in education falls under the category of applied art (Kruger 2008:37), which can be used as an educational tool for the promotion of the personal, social, and emotional development of learners in the science classroom (Simon et al. 2008:1231). The use of puppets in the science classroom to present arguments might help learners to engage in a dialogue and consider alternative perspectives on scientific ideas in a non-threatening situation (Simon et al. 2008:1232).

According to Simon et al. (2008:1231), using puppetry art as a teaching tool will help teachers to actively engage the learners in the science classroom. As stated by the scholar, puppetry art may be used to engage with the content of natural sciences to make the abstract content more meaningful and easier for the learners to internalise and apply the knowledge (De Beer 2015:1). Figure 2.1 below illustrates how teachers' engagement with natural sciences subject content using puppetry art, as well as the teachers' confidence, may contribute to the improvement of learners' positive attitudes and accomplishments in the subject (Sasway & Kelly 2020:14).

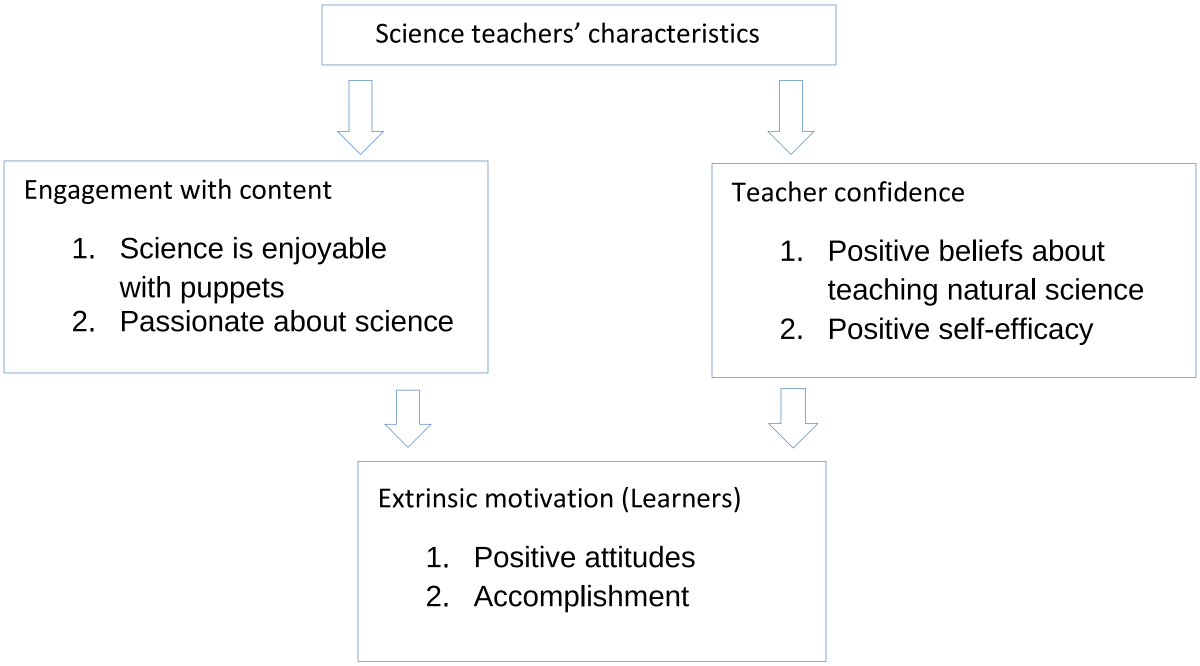

Figure 2.1 shows how teachers' engagement with the content using puppetry art might help in promoting learners' positive attitudes towards natural sciences (Sasway & Kelly 2020:14).

The application of puppetry art as a teaching tool introduces a different style of interpersonal relationships which may be very productive for science learning. In figure 2.1, one can see that engagement with science content through puppetry art might make science more enjoyable and enhance learners' attitudes and accomplishments in the subject. This is because the use of puppetry art in whole class teaching may provide a stimulus for discussions that may involve learners in reasoning, arguments, open questions, and justification of ideas as part of the process of solving a problem (Simon et al. 2008:1231).

Puppet characters can have "problems" for the learners to solve (Simon et al. 2008:1245). The learners might treat the puppets as though they were real characters in the classroom and respond positively to any problems posed by the puppets. According to Sasway and Kelly (2020:3-14), learner-centred strategies may improve the academic climate, attitudes towards science and learners' confidence and self-worth, making science learning more engaging.

The use of puppets as teaching tools could also allow the teachers to take on new roles in the classroom. While using puppets, teachers could model behaviour and learning conversations without appearing to intervene as authority figures. This may enhance teachers' confidence, positive beliefs and self-efficacy in science (Simon et al. 2008:1231).

The use of puppetry art as educational tools in the science classroom, therefore, has the potential of making a positive impact on the attitudes of the learners (Simon et al. 2008:1246) because it aids scaffolding, which is crucial for the guided construction of knowledge. This may enable learners in their peer group interactions, to have alternative opportunities for cognitive development, due to their exposure to reasoning that is superior to their own (Simon et al. 2008:1241). This is evidenced by the Team Hyena Puppet (THP) project.

The Team Hyena Puppet (THP) is an interdisciplinary project that uses art (puppets and dance) to teach science. The team utilises dance to represent the cell cycle and uses puppets in the teaching of biology. This transformed a previously dry section of a biology course into a memorable and meaningful event for the learners, and their performance in examination improved tremendously (Trommer-Beardslee, Dasen, Pangle & Batzner 2019:46).

Puppets may evoke thoughts, associations, feelings and intentions during their interaction with learners, and in the form of recollections after a lesson (Ahlcrona 2012:173). This can be attributed to their influence on the attitudes of the learners through their external properties such as appearance, movement, speech and action (Ahlcrona 2012:172).

Puppets therefore use the power of "affect" in shaping positive attitudes of learners, because "affect" is a sensation or a flow of energy which can be transformed into an action, a thought or interaction (Sloan 2018:585). This action, thought or interaction has a powerful influence on learners' affective domain, thereby influencing their attitudes (Sloan 2018:584).

Levy (2002:53) further elaborates on the benefits of using puppetry art as a pedagogy for the science teachers. These benefits include having a personality that is appealing to their learners and fellow teachers, and being more confident, which positively impacts their teaching style. Furthermore, teaching with puppetry art gives teachers a safe avenue through which they can enjoy the fun and zany aspect of teaching. He concludes by adding that such teachers would probably not suffer from professional burnout as soon as others would.

The use of puppetry art as a teaching tool also enables the teacher to view the lesson from the learners' perspective, incorporating their ideas and feelings into the lesson presentation so that the learners can relate to the puppet (Levy 2002:51). According to Levy (2002:50), Simon et al. (2008:1246) and Ahlcrona (2012:172), the use of puppetry art as a teaching tool promotes the development of positive attitudes in learners towards their studies, because the puppets influence the imaginary world of the learners and improve their creativity (Güçlü & Çay 2017:130).

Natural sciences is a fusion of the major branches of science. Its study will equip learners with the necessary process skills and values to provide a strong foundation for further study in science (Yeboah, Abonyi & Luguterah 2019:4). Natural science knowledge, therefore, is generated when learners interact with the content and teachers utilise appropriate instructional scaffolds to make learning a journey of discovery filled with adventure, curiosity, and wonder (Yeboah et al. 2019:3). To make natural science learning a journey of discovery, the use of puppetry art as a teaching tool becomes an option. According to Ahlcrona (2012:177), the puppet, by virtue of its hidden property of appearing to be living in the interaction in the science classroom, has the capacity to evoke affective complexes and generate emotions in the learners.

In order to comprehend the power of affect in influencing attitudes, Sloan (2014:220) describes the affective experience as a feeling of relaxed alertness. He calls it a positive and pleasurable sensation associated with spontaneous creativity. Affect has often been considered as an integral part of art (Turkka et al. 2017:1406) and has been described as an "indiscriminate convergence of multiple potentials at any moment into becoming a being, which activates connectivity" (Sloan 2018:586).

This might explain why the use of puppetry art in the teaching and learning of natural science might spur creativity (Güçlü & Çay 2017:130; Sloan 2018:593) and influence positive learner attitudes. This will have the capacity to enable learners to grasp and assimilate the content much more easily (Yeboah et al. 2019:3).

According to Levy (2002:52), the use of puppetry art as a teaching tool might have a number of benefits for the learners. This includes helping to establish a safe atmosphere for follow-up discussions about learners' feelings on issues that matter to them. It might also help to increase humour in the classroom, which can turn the teaching of scientific concepts into long-lasting memories. He further emphasises the power of the puppets in reaching out and touching the hearts of the learners, firing up their imagination and creating the "other personality" that brings excitement and drama to the science lesson.

The dual nature of the puppet in communicating ideas i.e. visual and symbolic (Kruger 2007:72), has the capacity to positively influence learners' attitudes towards natural sciences and improve their achievements as well. In a project carried out by Belohlawek et al. (2010:36-37), it was determined that using puppets to engage the learners in a lesson developed their thinking about concepts in science in an inquiring and exploratory approach. This was evidenced by the learners' high levels of consistency, engagement, and motivation. They employed more reasoning, gave more explanations and justified their ideas better in the science lesson (Simon et al. 2008:1231; Sloan 2019:584).

According to Simon et al. (2008:1245), the use of puppetry art in teaching science enhances the engagement and interest of the learners, as well as the teachers' beliefs and practices. The use of puppets as a teaching tool in natural sciences may help learners to develop emotional values. This may enable them to perform communication acts based on knowledge–related and emotional motives, which oversteps the boundaries between the actual and imagined worlds (Ahlcrona 2012:180). Güçlü and Çay (2017:130) reinforce this statement by adducing that puppets are important in education because they are familiar figures which may affect the imaginary world of the learners and improve their creativity.

According to Kruger (2008:41), incorporating puppetry art into the teacher's teaching strategy may be a powerful and stimulating tool in the classroom. Ahlcrona (2012:172) describes the power of puppets, when applied in the context of teaching and learning of science, as able to evoke and arouse the learners' emotions, thoughts and associations, which positively impacts their attitudes. It can also help them to form recollections, which consolidates their learning (Ahlcrona 2012:173).

In a study carried out by Najami et al. (2019:108), in which they used puppetry art to teach chemistry to tenth grade middle school learners, they found that the use of puppetry art in teaching had a positive effect on the learning of various chemistry topics. The learners were found to have better scores than those taught without puppets. Moreover, the learners had a more positive attitude towards learning chemistry. The scholars, therefore, proposed that the inclusion of the puppets as a teaching tool in the chemistry curriculum might help the learners to gain a better understanding of the concepts that may be difficult to comprehend when using traditional teaching methods.

The use of puppetry art in education offers a range of opportunities to develop the learners. This includes decision-making, exploring experiences, interacting with others, self-discovery, specific skills, and handling materials. It also makes learning memorable and stimulates learner engagement. This can be attributed to the power of the puppets as versatile tools for communication and learning (Ahlcrona

2012:182). Puppetry art may be incorporated into the teaching of sciences to stimulate learners' positive attitudes and improve their performance, since the puppets' characters are detached from the teacher's persona. They therefore add a unique teaching dimension that is flexible and controllable (Pearce & Hardiman 2012:445).

The use of puppetry art as an alternative teaching aid may improve the self-efficacy of the teachers and learners and make the teaching and learning of natural sciences more interesting (McGregor & Knoll 2015:339) and meaningful. This could aid in helping to achieve the desired change in attitude towards the subject within the context of the STEAM educational approach.

In the next section, the researcher will discuss the application of the cultural-historical activity theory (CHAT) as a lens through which the effectiveness of puppetry art as a learning tool for attitude change within the context of the STEAM educational approach will be examined and explained.

2.4 The cultural-historical activity theory, CHAT: a historical perspective

Vygotsky (1978) posits that learning always depend on its specific social, cultural, and historical formation, and that learners' participation in learning is mediated by tools that modify how they achieve the objectives of the learning exercise. These tools (the STEAM approach and puppetry art) might help to shape how they interact with the content. The theory was further expanded on and modified by Engeström (1987:78), to present what we now know as the third generation cultural-historical activity theory (CHAT).

According to the CHAT, the primary unit of analysis for understanding human knowledge and practices is a collective artefact-mediated and object-oriented activity system. In this system, the individual and group actions are subordinate units of analysis, understandable only when interpreted against a background of the entire activity system (Engeström 2001:136). Within this context, CHAT views activity systems as the central and determining factor regarding human learning and knowledge construction (McMurtry 2006:209). The cultural-historical activity theory (CHAT) therefore allows us to think in new and productive ways about individual development, generally, and about learners' development of positive attitudes towards natural sciences, specifically (Roth 2012:96).

The cultural-historical activity theory (CHAT) is an alternative social–psychological theory for understanding and explaining human behaviour, such as learning, in its concrete and material details (Roth 2006:22). It is based on the work of Vygotsky, and it focuses on changing the conditions in which learning takes place (Roth et al. 2009:132). An activity is culturally and historically contingent, so is the learning that arises from participating in such activity (Roth et al. 2009:141). According to the origins of the CHAT theories, certain psychological phenomena such as motivation and goal setting in learning are grounded in our interactions with others, our surroundings, cultural norms, and historical precedents (DiSarro 2014:439).

The CHAT activity system recognises that goal-directed actions are derived from the collective motives of life-sustaining human activities (Roth et al. 2009:132). This infers that activity systems are goal-directed and historically situated in cooperative human interactions. In this regard, nearly anything that one does can be considered as part of an activity system, as long as there are discernible goals, historical precedence, and collaborative efforts amongst participants (DiSarro 2014:440). An example of this can be observed in a science classroom, where a natural sciences teacher is engaging with the content using the STEAM approach and puppetry art as tools. The learners therefore are involved in an already existing societal endeavour concerning effective learning, which might lead to them developing a more positive attitude towards natural sciences.

The CHAT is a model of an activity system that is constantly evolving through collective learning actions. It enables the analysis of complex practices such as learning natural sciences and developing positive attitudes towards it (Foot 2014:330). In recent years, the work of Engeström has helped to compartmentalise the activity theory. It breaks human behaviour and consciousness into a series of multi-phased processes and establishes a manageable node of contexts within the activity system. This can be analysed in order to observe, infer and reflect upon human behaviour, interactions, motivations and the influence of internal and external factors on the environments in which those individuals operate (DiSarro 2014:440).

According to Foot (2014:330), each word in the name "cultural-historical activity theory" is significant. Culture depicts that humans are enculturated, and that everything they do is shaped by their cultural values. The term historical is used together with cultural to indicate that culture is grounded in history and evolve over time. Individuals' actions must therefore be viewed in the light of the historical perspectives in which they occur. The term activity refers to what individuals do together, and it is modified by both cultural and historical 'situatedness'.

According to Engeström (2001:136), the cultural-historical activity theory may be summarised with the help of five principles: (a) the primary unit of analysis is a collective artefact-mediated and object-oriented activity system, (b) an activity system is always a community of multiple points of view, traditions and interests. This is a source of innovation, demanding action or translation and negotiation. (c) Activity systems take shape and get transformed over long periods of time. Their problems and potentials can only be understood against their own history. (d) Contradictions are a source of change and development. Contradictions are historically accumulating structural tensions with and between activity systems. (e) There is a possibility of expansive learning in activity systems.

Below is an illustration of Engeström's second generation CHAT activity system as a unit of analysis. It comprises of an organisation, for example a school, where teachers and learners cooperate to perform an activity such as learning. The top section of the triangle in the activity system (see figure 2.2) depicts the *subject,* whose actions are mediated by *tools* towards the realisation of the *object* or *objective* of the activity. The actions of the *subject* are situated within the social realm at the base of the triangle, which includes *rules*, *community,* and *division of labour*. The arrows indicate the dynamic nature of the interrelationships that exists in the activity system (Engeström 2001:134). The teachers and learners in the activity system socially interact, and by so doing develop each other (Roth et al. 2009:141).

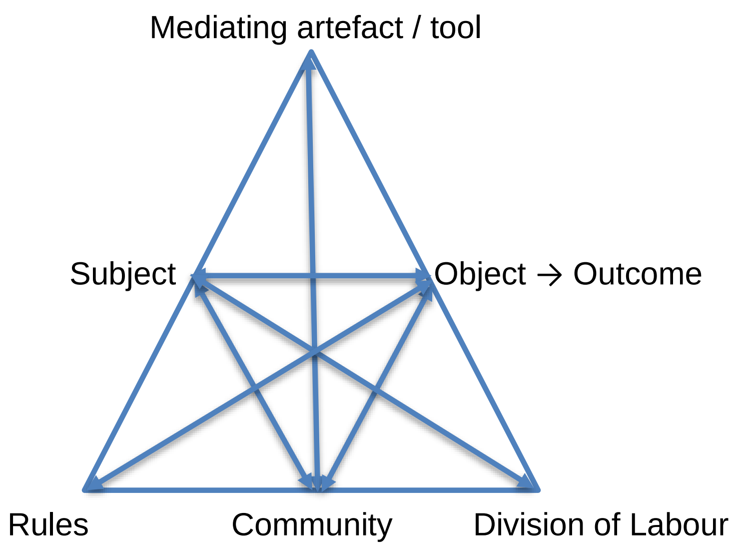

Figure 2.2 The CHAT activity system (Engeström 1987:78)

The theory's importance lies in its versatility and the fact that it can be applied to a variety of situations in the classroom (Nussbaumer 2012:45). Engeström's third generation cultural-historical activity theory (CHAT) therefore provides a theoretical basis for the argument on the use of puppetry art within the context of the STEAM educational approach as a teaching tool to, influence an attitude change of learners towards natural sciences (De Beer 2015:1) in the classroom.

The basis for this argument is that learners' attitudes towards natural sciences may be positively enhanced through the science teachers' application of puppetry art as a teaching tool within the context of STEAM to create an effective entry point towards making the abstract natural science knowledge more concrete and accessible (De Beer 2015:1) to them. This might lead to a change in their attitudes towards the subject.

CHAT is not without certain limitations, nor is such a framework ideal for the interrogation of all activity–based paradigms. Despite the limitations of the CHAT activity system, it will be nonetheless utilised as a theoretical framework in this study to understand and explain the use of puppetry art as a teaching tool for attitude change within the STEAM educational approach in natural sciences (DiSarro 2014:449). The CHAT activity system will therefore be used to denote the theoretical framework for understanding and explaining the effective integration of puppetry art as a teaching tool within the context of the STEAM approach, and its relationship to the objectives of the study.

2.4.1 Applying the cultural-historical activity theory CHAT, as a theoretical lens

My approach in this study is to apply Engeström's second and third generation cultural-historical activity theory (CHAT) activity systems as a theoretical lens through which to examine the application of puppetry art as a teaching tool within the context of the STEAM approach. This is aimed at a possible change in the attitudes of the learners towards natural sciences through expansive learning, caused by the tensions and contradictions between the object's outcomes of the puppetry art-STEAM approach and the traditional approach. According to Roth (2012:90), activity is the basic category of the cultural-historical activity theory (CHAT). It is the smallest analytic unit for understanding human performance, their practices, the sense they make or the actions they perform. Activities are therefore concretely realised by goal-directed actions, but actions are performed because they realise an activity (Roth 2012:91).

The CHAT activity system is concerned with human knowledge and practices (Roth et al. 2009:132). It has been described as a multifaceted clarifying tool, capable of being utilised in a variety of disciplines in order to understand and analyse human learning, as well as changing the conditions in which we learn (DiSarro 2014:438). The theory offers a theoretical framework both epistemologically and methodologically for analysing and examining the application of puppetry art as a teaching tool for learners' attitude change towards natural sciences within the context of the STEAM educational approach (Foot 2014:330; Silo 2013:160).

Previous research indicates that learners' attitudes towards science are declining (Kennedy et al. 2014:34; Villafuerte et al. 2015:477; Fernández Cezar & Solano Pinto 2017:112; Reddy 2017:26). This decline may be attributed to many factors, including science learning seeming much more difficult due to ineffective teaching methods (Hampden-Thompson & Bennett 2013:1327; Wan & Lee 2017:508; Mujtaba et al. 2018:645). According to Daniels (2001:70), learning is socially constructed through the collaborative efforts of teachers and learners to achieve shared objectives in culturally specific surroundings. Therefore, the integration of puppetry art as a tool in natural sciences learning within the context of the STEAM educational approach might provide the much needed creativity, critical thinking and problem-solving to promote learners' attitude change towards natural sciences (Sousa & Pilecki 2013:11).

Although interest in the CHAT activity system has increased over the years, science educators are yet to harness its full potential to understand human knowing and learning (Roth et al. 2009:132). In the CHAT activity system, knowing and learning are studied in context, where context is understood to be collectively motivated human activities (Roth et al. 2009:133). The cultural-historical activity theory therefore has much to offer science educators as it opens a new era for research and new ways of theorising phenomena that emphasise relations and histories (Roth 2012:101).

The integration of puppetry art as a learning tool might be valuable for science learning since its importance is rooted in the constructivist learning paradigm (Turkka et al. 2017:1404). This paradigm is based on the principle that new ideas are integrated into existing knowledge (Silo 2013:161; Turkka et al. 2017:1404). For instance, the use of artefact-mediated learning might help learners to link abstract concepts in natural sciences to an authentic context to support learning (Turkka et al. 2017:1405). Since knowledge integration is a cognitive process, the integration of the STEAM approach and puppetry art as a tool might become an option to promote effective science learning. This is due to their ability to provide multiple ways to express and explore the natural science content (Turkka et al. 2017:1407).

The CHAT is one of several practice-based approaches that provides a framework for analysing work practices. It also offers a multi-dimensional, systemic approach that includes both psychological motives and tools (Foot 2014:329). In other words, it provides a framework for analysing the interactions between science teachers and their learners in cultural and historical dimensions (Foot 2014:328).

The cultural-historical activity theory is centred on three core ideas. The first is that humans learn by doing and communicate via their actions. Secondly, they employ tools to learn and communicate. Thirdly, the community is central to the process of making and interpreting meaning (Foot 2014:336). The CHAT activity system provides a useful way of systematically explaining human activities in an educational context, in which change in learners' attitudes is mediated through the introduction of new tools (Cliff, Walji, Mogliacci, Morris & Ivancheva 2020:6) such as puppetry art within the STEAM approach into an already existing complex learning system.

Therefore, only in the study of a concrete productive activity, such as learning natural sciences, and the actions that constitute it, can we simultaneously identify the *object* and the *subject,* while producing the *outcome*. The *outcome* produced by the *subject* is mediated by the *tool* (Roth et al*.* 2009:141). The CHAT activity system therefore presents a useful framework for science educators to conduct a more holistic, contextualised analysis of pedagogical practices (DiSarro 2014:441).

2.4.2 The interactive relationships between the components of the puppetry art-STEAM approach within Engeström's (1987:78) activity system model

According to Engeström (2001:134), the *subject* uses interpretation, sense-making and potential for change in the pursuit of the *objective (object)* of the activity.

Together, the *object* and the anticipated *outcome* constitute the motive of the activity (Roth et al. 2009:140). The objective of the study, as stated in Chapter 1, is to formulate recommendations and/or guidelines on how to integrate puppetry art within the context of the STEAM approach, as a learning tool for attitude change of learners in natural sciences. According to Engeström (2001:135), Roth et al. (2009:132) and DiSarro (2014:441-443), in applying CHAT to the integration of puppetry art within the STEAM approach as a tool in the teaching of natural sciences, the components of the activity system represent the following:

The tools

These are the mediating artefacts or means that are utilised by the *subject* in the performance of the activity (see figure 2.3). *Tools* can either be material or conceptual (Foot 2014:5). They are the symbols or conceptual understandings that serve as physical and psychological artefacts mediating between the *subject* and the *object*. In the context of the study, the *tools* represent puppetry art within the STEAM educational approach (see figure 2.3). It is the mediating artefacts that transforms the *object* into an outcome (Postholm 2015:51). These are applied as a learning mediating artefact by the *subject* to enhance the creativity and problem-solving abilities of learners in natural sciences. This enhances the learning of abstract concepts in natural sciences by making them more concrete (Turkka et al. 2017:1405). This might lead to the development of new beliefs which may enhance learners' self-efficacy in the subject. The use of these artefacts can be interpreted as the teacher's creative ideas aimed at enhancing the teaching and learning of natural sciences (Batiibwe 2019:13).

The subject

The *subject* uses the mediating artefacts or *tools* as aids to attain a goal-directed action (Postholm 2015:45). The *subject* (see figure 2.3) in the study represents natural sciences teachers who apply puppetry art within the STEAM approach (the *mediating artefact* or *tool*) as a means to enable the learners to actively construct natural sciences knowledge by linking the abstract concepts in natural sciences to authentic context in order to support learning (Turkka et al. 2017:1405; Batiibwe 2019:11). This is aimed at a goal-directed action of achieving attitude change of the learners towards natural sciences.

The rules

According to Postholm (2015:45), *rules* include norms and conventions that direct actions in the activity system. In this context, the *rules* (see figure 2.3) represent the cultural norms or rules in learning. They are the parameters on how an activity will be done, for instance, the limitations, or what is allowed in the activity. Therefore, the *rules* represent how the learners will be assessed during the activity by the teacher. The rules will indicate when assessment will be conducted and how it can be done.

The community

The *community* (see figure 2.3) represents the environment in which the activity will be carried out, or the institution that has influence over the activity. In this context, it represents the schools where the learning of natural sciences takes place. On the micro level of the classroom, the *community* revolves around the idea of fostering a sense of togetherness amongst the teachers and learners (DiSarro 2014:442).

The division of labour

The *division of labour* (see figure 2.3), in simple terms, depicts who is responsible for what during the goal-directed action. This can also be explained in terms of the authority exchanged between the teachers and the learners, because without power, there is only randomness (DiSarro 2014:443). In the context of this study, therefore, the *division of labour* is mediated by the teacher.

The object

The *object* (see figure 2.3) can be examined in the light of the *objective* of the activity or why the activity is taking place. It represents the *objective* that the *subjects* hope to accomplish through engaging in the specific activity. The *object* therefore is synonymous with the purpose of the activity. It refers to the materials that are transformed and turned into the *outcomes* (Roth 2012:92). According to DiSarro (2014:444), the purpose behind any given activity is linked to the motive or motivations of the *subject*. Andrews, Walton and Osama (2019:4) describe the *object* as the 'sense maker' that gives meaning and determines the value of the various phenomena. It is also as the dynamic entity that is constructed and transformed by the various constraints that exist in the system, such as the need the activity aimed to satisfy. The *object* of activity in this study therefore are natural sciences learners, in whom an attitude change towards natural sciences, the *subject* (see figure 2.3), were aimed for by the integration of puppetry art as a teaching and learning *tool* within the STEAM educational approach.

The outcome

The outcome (see figure 2.3) are the desired *outcomes* of the activity. It exists in the consciousness, ideally from the beginning, and serves as the activity-driving motive (Roth 2012:92). It can be explained in terms of what the activity will accomplish in both the short and long term. The *outcome* for the study therefore will be the achievement of learners' attitude change towards natural sciences.

Figure 2.3 below illustrates the interactive relationships between the components of the puppetry art-STEAM approach within Engeström's (1987:78) activity system model, and their roles towards the realisation of the objectives of the activity.

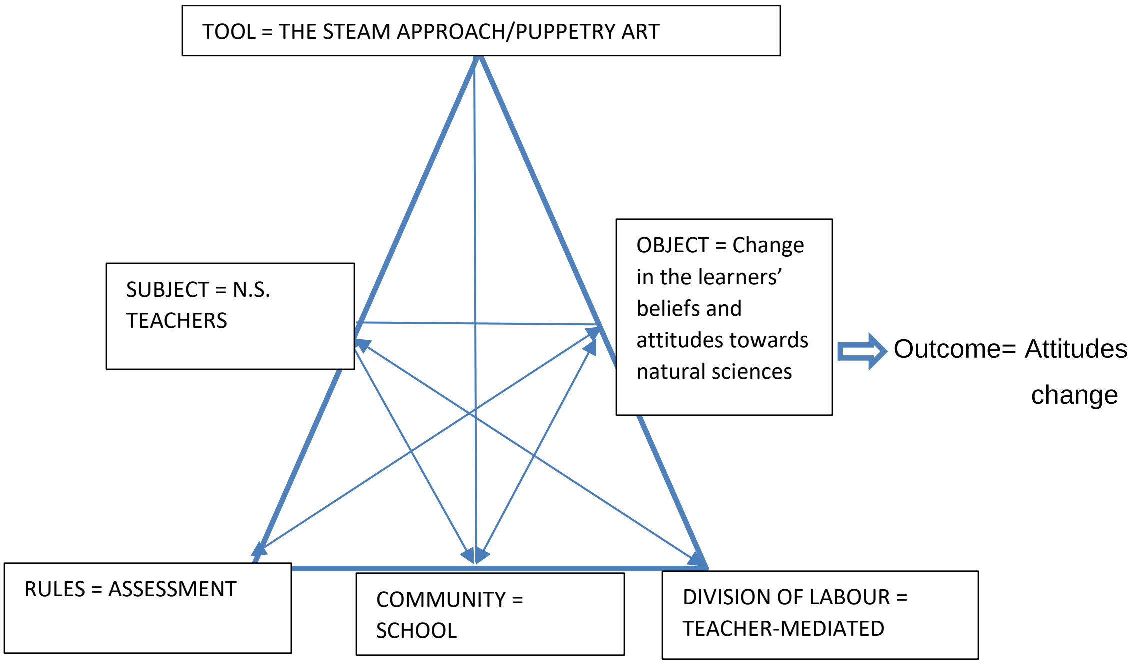

Figure 2.3 The CHAT activity system for the integration of STEAM-puppetry arts into natural sciences learning (Engeström 1987:78)

According to Roth et al. (2009:146), tool mediation is very important in learning because it captures the relationship between the *subject* and *object* in an activity system. It is also closely associated with the *community* and *division of labour*. From the perspective of the CHAT activity theory, the learning of natural sciences, mediated by the integration of the STEAM approach and puppetry art is an outcome of communities of practice (Jho, Hong & Song 2016:1845).

In the next paragraphs, the researcher will discuss how the interaction between the *objects* of the two activity systems, i.e. the puppetry art-STEAM approach and the traditional teaching approach, might lead to expansive learning and attitude changes.

2.4.3 The 3rd generation activity system, expansive learning, and attitude change

Expansive learning is accomplished when the object and motive of the activities are reconceptualised to embrace a radically wider horizon of possibilities than in the previous mode of the activity (see figure 2.4). This is defined as a collective journey through the zone of proximal development of the activity (Engeström 2001:137). According to Roth and Lee (2007:28), learning occurs when an artefact (puppetry art as a teaching tool within the STEAM approach) constitutes a new possibility for learners at the level of the individual or group in the activity system, which may lead to an increase in generalised action. This is corroborated by Lin and Yudaw (2013:443), who state that an introduction and collaborative application of new tools as mediatory artefacts (i.e. puppetry art) is key to transformation and innovation in learning.

Expansive learning actions are provoked by tensions and contradictions. Different levels of contradictions might occur when two activity systems interact (e.g. puppetry art/STEAM and traditional approaches). It may be between two *objects* of activity systems, or between two activity systems (Roth & Lee 2007:25). When these contradictions are brought about consciously, they can lead to a change that transforms the *objects* of the two activity systems, which eventually leads to expansive learning (see figure 2.4) (Engeström 2001:136; Roth & Lee 2007:204).

Transforming contradictions into potentials of growth is central to CHAT analysis, because the process of resolving a contradiction is also the process of concept formation (Lin and Yudaw 2013:450). Therefore, the tensions and contradictions that might lead to expansive learning, according to Postholm (2015:46), may be between a newly reorganised activity system and the remnants of the previous activity system. In the context of the study, tensions and contradictions may arise between the newly reorganised puppetry art/STEAM approach activity system, and the remnants of the traditional approach. This might lead to expansive learning and possible attitude changes.

Contradictions in this instance are not the same as problems or conflicts. They should rather be seen as historically accumulating structural tensions within and between activity systems. For example, when an activity system adopts a new tool from outside (e.g. using puppetry art as a teaching tool within the STEAM approach), it might lead to an aggravated tertiary contradiction (Engeström 2001:137) where some old elements (e.g. traditional teaching methods) collides with the new (the puppetry art/STEAM approach).

Such contradictions in natural science learning might be caused by the differences in the *objects* of the puppetry art/STEAM approach activity system and the *objects* of the traditional approach. In other words a difference may arise between learners who are taught ecology with the aid of puppetry art, which may provoke critical thinking and problem-solving, and learners who are taught with the aid of textbooks (Roth & Lee 2007:26). Expansive learning therefore produces new patterns of culturally activity (Engeström 2001:139) that might enable learners to form new learning possibilities due to the use of puppetry art as a mediatory tool by the *subject* to mediate learning (Roth & Lee 2007:28). This might also lead to an attitude change toward natural sciences.

According to Foot (2014:19), the following sequence of learning actions, resulting from tertiary contradictions, might lead to expansive learning:

(a) The learners questioning, criticising or rejecting some aspects of the accepted practice and existing wisdom associated with the traditional approach.
(b) The learners analysing the situation in order to identify causes or explanatory mechanisms by constructing a picture of its inner systemic relations.
(c) Modelling the newly found explanatory relationship in some publicly observable and transmittable medium.
(d) Examining the use of puppetry art as a mediating artefact in order to grasp its potential and limitations.

(e) Implementing the model through practical application and conceptual extension.
(f) Reflecting on and evaluating the process of learning new concepts in natural sciences through the puppetry art /STEAM approach.
(g) Consolidating its outcomes into a new stable form of practice.

Expansive learning might therefore lead to a change in learners' attitude towards natural sciences, as was proposed by Engeström (2001:136), through the following three steps. (a) The *object* of activity moves from an initial state of "unreflected" situationally-given "raw material" (*Object* 1) - see figure 2.4. In the context of this study, this depicts a natural sciences learner who is well-acquainted with the traditional approach walking into the classroom where the natural science teacher introduces the lesson with the aid of puppetry art. (b) The learners' beliefs and attitudes towards natural sciences become a collectively meaningful *object* constructed by the puppetry art/STEAM approach activity system (*Object* 2). (c) The *object* moves to a potentially shared or jointly constructed *object* (*Object* 3) (Engeström 2001:136).

The *object* of activity (e.g. learners' attitudes towards natural sciences) is a moving target, not reducible to conscious short-term goals (Engeström 2001:136). Expansive learning, therefore, is motivated by the promise of the expansion of the power to act that is available to individual learners (Roth et al. 2009:139). By applying the CHAT framework as a theoretical lens, the researcher takes a more systemic and thorough approach to understanding the factors that might shape how the integration of puppetry art as a tool might lead to a change in the attitude of the learners towards natural sciences (Trust 2017:101).

The integration of puppetry art into the teaching and learning of natural sciences might therefore lead to expansive learning, resulting in learners' attitude change towards natural sciences. The interactions of the *objects* of activity (see figure 2.4) of the traditional approach and the STEAM approach (puppetry art) might introduce tertiary contradictions (Roth & Lee 2007:26) between the traditional teaching approach (where learners are expected to memorise and define certain words related to ecology) and the STEAM educational approach (where learners interact with puppets to learn ecology). The learners therefore might question, criticise, or reject some aspects of the accepted practice and existing wisdom of the traditional approach. This in turn might lead to their modelling the newly found explanatory relationships (Engeström 2001:137; Foot 2014:19) of the STEAM approach, reflecting on and evaluating its process leading to the consolidation of its outcomes into a new stable form of practice (Engeström 2001:137; Roth et al. 2009:139) which might lead to their attitude change towards natural sciences.

Figure 2.4 illustrates how expansive learning might occur through the interaction of the objects of the two activity systems (the STEAM approach and the traditional approach), which might lead to an attitude change of learners towards natural sciences.

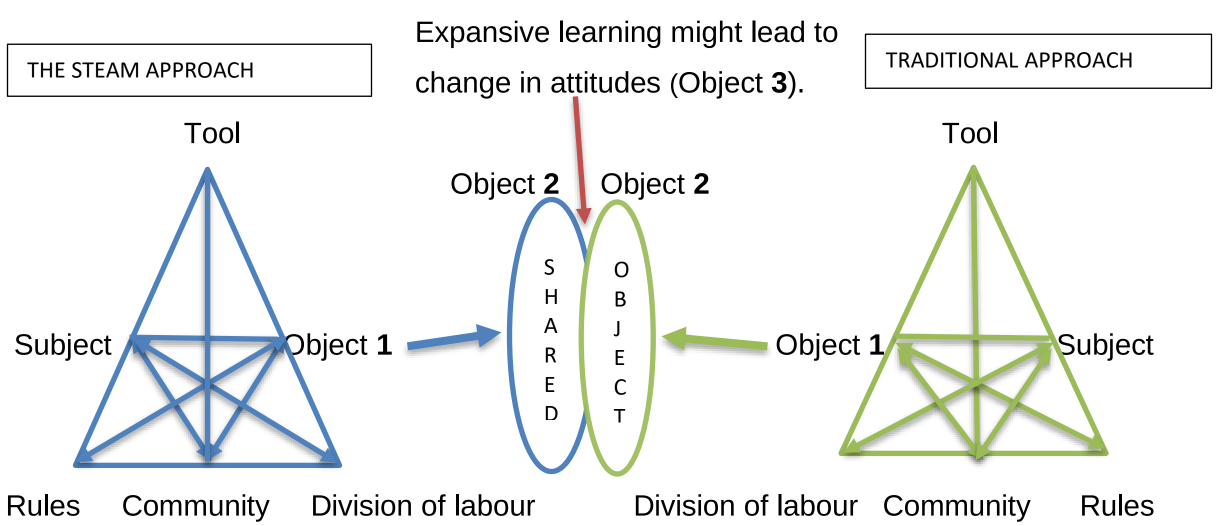

Figure 2.4 Expansive learning (Engeström 2001:136; Roth et al. 2009:139).

The significance of learning natural sciences using puppetry art as a tool is an outcome of communities of practices or situated learning. A community of practice, therefore, is a place of learning where practice is developed and pursued, and where roles are developed through various forms of engagement and participation (Jho et al. 2016:1845).

2.5 Conclusion

The purpose of reviewing the existing literature on the STEM (Science, Technology, Engineering and Mathematics) and STEAM (science, technology, Engineering, Arts and Mathematics) educational approaches, the significance of the STEM to STEAM shift, as well as the theoretical lens that was used to view the integration of puppetry art as a teaching tool in natural sciences, aimed to establish a solid theoretical foundation for this study.

Some of the challenges identified by the researcher from the reviewed literature include the significance of ineffective teaching approaches and tools in deterring learners from embracing school science as a subject of choice. Secondly, the learners' accomplishments in school science subjects are greatly impacted by their teachers' use of ineffective teaching approaches and tools. This also affects teachers' self-efficacy and classroom practices, and finally. It was further identified that learners' attitude towards school science subjects has been declining over the years. The researcher was able to establish from the literature that the incorporation of the arts in the teaching and learning of science, improves learners' outlook and interest in school science subjects, through the promotion of creativity, as well as enhancing teachers' self-efficacy towards the teaching of science subjects.

Given the various challenges identified from the reviewed literature, the current study will attempt to address how puppetry art can be integrated into the teaching and learning of natural sciences. This will promote creativity, thereby making natural sciences learning more interesting, attractive and fun for the learners. This might help in developing learners' development of a positive attitude towards the subject, and enhancing teachers' self- efficacy, thereby influencing positive attitudes towards the subject. The cultural historical activity theory (CHAT) was also used as a theoretical lens through which to view and further explain the significance of the integration of puppetry art as a teaching tool in natural sciences within the context of STEAM education for positive attitude development outcomes.

In the next chapter, the researcher will review relevant literature on attitudes to establish the influence of attitudes in the teaching and learning outcomes in natural sciences. The conceptual framework that espouses the integration of puppetry art as a teaching tool for attitude change in natural sciences will also be discussed in order to establish a solid theoretical basis for the argument on the integration of puppetry art as a teaching and learning tool in natural sciences.

CHAPTER THREE

LITERATURE REVIEW ON ATTITUDES TOWARDS SCIENCE AND THE CONCEPTUAL FRAMEWORK

3.1 Introduction

The studied literature emphasised the importance of a positive attitude by learners and teachers in the effective teaching and learning of science in schools (Van Aalderen-Smeets, Van der Molen & Asma 2012:159; Van Aalderen-Smeets & Van der Molen 2013:584; Wan & Lee 2017:509; Fernández Cezar & Solano Pinto 2017:113; Karamustafaoğlu & Bayar 2018:119; Hassan 2018:2045; Mujtaba et al. 2018:646; Hacieminoglu 2019:63; Oon, Cheng & Wong 2020:91). The question arises as to how these positive attitudes towards science can be achieved in a traditional classroom, and this was not answered from the literature.
Some additional questions include: Can the attitudes of learners towards science be positively influenced through the integration of the arts in the teaching and learning of science? Can the integration of the arts in science education influence creativity, which may improve the declining attitudes of learners towards science? How can science teachers creatively integrate the use of arts into their science lesson plans to positively influence learners' attitudes towards science?

In this chapter, a study of the relevant literature was done to establish the theoretical basis for addressing these questions and the research questions, as well as achieving the objectives of the study as formulated and stipulated in Chapter 1.

Several studies by different scholars have revealed that the more positive learners' attitude towards science, the deeper their interest in the scientific content (Fernández Cezar & Solano Pinto 2017:113; Hacieminoglu 2019:63). For the learners to develop a positive attitude towards science, the science teachers' level of involvement, high levels of personal support, strong positive relationships, and the use of a variety of teaching tools and strategies as well as positive self-efficacy becomes paramount (Osborne et al. 2003:1066; Wan & Lee 2017:508; Ambusaidi & Al-Farei 2017:73; Oon et al. 2020:92). The learners' positive attitude towards science, therefore, is a catalyst towards outstanding academic achievement, and also reflects on the development of practical and logical reasoning abilities (Osborne et al. 2003:1066; Kind et al. 2007:872; Wan & Lee 2017:509; Hassan 2018:2046). Teachers play a key role in the positive attitude development of learners towards science (Hassan 2018:2047), because teaching addresses cognition (thinking), and affective (emotion and values) and behavioural (action) determinants of learners' attitudes towards science (Hassan 2018:2046), which may influence how they embrace the subject.

In the next section the researcher will define the type of attitudes towards science that are addressed by the study.

3.2 Defining attitudes towards natural science

The attitudes defined in the context of this study are teachers' and learners' "attitudes towards natural sciences" as a subject, as opposed to "scientific attitudes". The attitudes towards natural sciences consist of a variety of thoughts, values, feelings, and behaviours. It also encompasses concerns regarding the levels of difficulty, enjoyment or interest of the learners and teachers towards natural sciences, which may inform their attitudes, as opposed to their scientific thinking (Ramsden 1999:127; Osborne et al. 2003:1045; Van Aalderen–Smeets et al. 2012:160; Van Aalderen-Smeets & Van der Molen 2013:581; Fasasi 2017:550; Chi, Wang, Liu & Zhu 2017:2172; Wan & Lee 2017:507; Hacieminoglu 2019:78; Aldahmash et al. 2019:5; Oon et al. 2020:92).

Van Aalderen–Smeets et al. (2012:160) describe “scientific attitudes” as consisting of features that characterise scientific thinking, such as curiosity, being critical about all statements, and a demand for verification or respect for logic. They further argue that scientific attitudes are important to the advancement of scientific inquiry in schools, but do not necessarily constitute what should be considered as attitudes towards science.

Wan and Lee (2017:509) and Aldahmash et al. (2019:5) describe the three determinants which may influence the attitudes of teachers and learners towards natural sciences. These are (a) cognition, which encompasses the perceived relevance and the perceived difficulty of natural sciences, (b) affect, which describes the feelings of anxiety or enjoyment of the learners and teachers towards natural sciences, and (c) perceived control, which emphasises self-efficacy, an internal sense of control such as their behavioural beliefs towards natural science (see figure 3.1).

A positive attitude, therefore, may be characterised by the experience of positive reactions and emotions towards natural sciences (Van Aalderen–Smeets et al. 2012:162; Van Aalderen–Smeets & Van der Molen 2013:584; Wan & Lee 2017:509; Chi et al. 2017:2127). These reactions and emotions of the teachers and learners towards natural sciences may therefore be influenced by their knowledge, beliefs and ideas (cognitive), their feelings about the subject (affective), and their tendency of action (behaviour) towards the subject (Hassan 2018:2046; Mujtaba et al. 2018:646).

These evaluative thoughts and beliefs of the learners and teachers about natural sciences may give rise to specific feelings, which may define the actions they will take towards it (Kind et al. 2007:3). Attitudes, therefore, may differ from moods and emotions. This implies that attitudes towards natural sciences are evaluative judgements about natural sciences, formed by the learners or teachers (Barmby &

Kind 2008:1077), which may have a profound impact on their behaviour towards the subject (De Houwer et al. 2013:253).

Attitudes are, therefore, very important in determining the intention to teach or learn (Yan & Sin 2015:216) natural sciences. The implication of this is that the attitudes of teachers and learners towards natural sciences may be determining factors on how they embrace it (Dohn 2016:188). In this context, it suggests that their attitudes may determine their inclination towards, and actions in, the subject, which is critical in its teaching and learning. This was affirmed by scholars who stated that learners' positive attitude towards natural sciences provoke their interest in the subject (Fernández Cezar & Solano Pinto 2017:113).

The importance of attitudes in the teaching and learning of natural sciences is further emphasised by Van Aaldereen-Smeets et al. (2017:238), who state that promoting learners' interest in learning natural sciences requires a positive attitude. It is also worthy to note that, if the attitudes of natural science teachers towards teaching the subject are positive, it reflects on their teaching practices, and also influences learners' positive attitudes (Ambusaidi & Al-Farei 2017:72) towards the subject.

Attitudes towards natural sciences are three-dimensional and can be defined as the acquired cognitive, affective and behavioural predisposition of learners or teachers towards natural sciences (see figure 3.1) (Fernández Cezar & Solano Pinto 2017:113). It is the tendency to display positive or negative behaviour towards natural sciences, or the psychological tendency of the teachers and learners to evaluate natural sciences in terms of its favourable or unfavourable attribute dimensions as either positive or negative (Pino-Pasternak & Volet 2018:1522; Karamustafaoğlu & Bayar 2018:119).

Figure 3.1 below summarises the different attitudinal beliefs of natural sciences teachers towards the teaching and learning of the subject, as was discussed in the preceding paragraphs. These can be summarised as the cognitive beliefs, normative beliefs, and behavioural control beliefs they hold towards the subject.

These may influence the teachers' attitudes, which may predict their behaviour towards the teaching of the subject (Van Aalderen-Smeets et al. 2017:241).

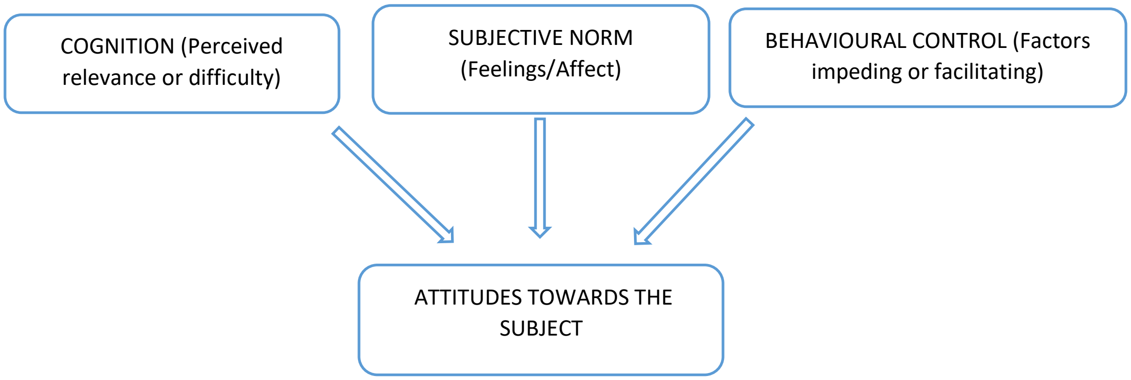

Figure 3.1 A representation of the three determinants of teachers' and learners' attitudes towards natural sciences (Van Aaldereen Smeets et al. 2017:241).

Having reviewed relevant literature on the nature and effects of attitudes towards natural sciences as well as the definition of attitudes towards natural sciences, the researcher will in the next section critically review the literature on the learners' and teacher's attitudes towards science, the continuous decline in learners' attitudes towards science, and its implications in the teaching and learning of natural sciences.

3.2.1 Learners' attitudes towards science

The promotion of favourable learner attitudes towards science has increasingly become a matter of concern (Osborne et al. 2003:1049). Over the years, records indicate that there has been a declining interest of learners in science (Van Aalderen–Smeets et al. 2012:150). This has been attributed by many scholars to the influence of learners' attitudes towards science. This is further influenced by their feelings, beliefs and values about science subjects (Osborne et al. 2003:1053; Fasasi 2017:551; Wan & Lee 2017:508; Mujtaba et al. 2018:645).

Research has also revealed that there is a significant relationship between learners' achievement in science and their attitudes. The more successful learners in science usually also have the most positive attitudes (Aslan 2017:2; Hacieminoglu 2019:63,78) than those who are less successful. Many scholars have also attributed learners' interest in science to their attitudes towards science, and have indicated that this could be further improved if the teachers use appropriate instructional materials/tools and apply a variety of teaching approaches (Ambusaidi & Al-Farei 2017:72; Hacieminoglu 2019:79; Sasway & Kelly 2020:2) in their science lessons.

Of the three determinants of attitudes, the affective determinant is considered the most important component because feelings and emotions play a significant role in attitude development (Güney 2013:226; Wan & Lee 2017:508; Mujtaba et al. 2018:646). The behavioural action towards the subject is the outcome of the three determinants (cognitive, affective and perceived control), and is the practical representation of attitudes which may result in either positive or negative actions towards science (Güney, 2013:227, Van Aalderen–Smeets & Van der Molen 2013:581; Oon et al. 2020:91). The implication of this is that learners will action positive behaviour in science if they have positive attitudes towards it (Güney 2013:228; Wan & Lee 2017:509). This view is also held by De Houwer et al. (2013:253) and Hassan (2018:2046), who mention that learners' attitudes towards science have a profound impact on their behaviour and/or actions towards it.

Lyons (2006:597) found that the nature of the scientific content of the curriculum may also lead to teaching being ineffective, and the perception of school sciences being difficult. Turner and Ireson (2010:119), in a separate study, corroborate the findings of Lyons, and conclude that learners' attitudes towards science may be influenced by ineffective teaching methods, which makes science seem difficult. The traditional science teaching methodology is teacher-centred and relies mainly on textbooks and "chalk-and-talk" and rote learning. This may reinforce learners' negative attitudes towards science (Toma, Greca & Orozco Gómez 2019:508).

Chetcuti and Kioko (2012:1585), in their study in Eastern Kenya, also found that learners' positive attitudes are influenced by the positive attitudes of their teachers towards the teaching of science. The influence of attitudes in the interest of learners towards science is further reported by Potvin and Hasni (2014:112) and Van Aaldereen–Smeets et al. (2017:238). In their respective studies these researchers emphasised the importance of positive learner attitudes in science in order to influence their interest in the subject. This also supports the findings of Fernández Cezar and Solano Pinto (2017:113), that learners' positive attitudes towards science provoke their interest in the subject.

In the next paragraphs the researcher will discuss the declining attitudes of learners towards science.

3.2.2 Declining learners' attitudes towards science

Observed patterns from research indicate that learners' attitudes towards science in schools have been declining over the years in many countries, including South Africa (Reddy 2017:26). This clearly indicates that the decline has gone beyond national and cultural boundaries (Hampden-Thompson & Bennett 2013:1326; Kennedy et al. 2014:35; Wan & Lee 2017:509; Toma et al. 2019:509), and has led to a significant decrease in the number of learners studying science in schools. It was also found to be more prevalent in learners in the higher grades than in the lower grades (Turner & Ireson 2010:129; Villafuerte et al. 2015:475) where science subjects are compulsory.

Many factors may have been responsible for this decline in the number of learners doing science, including science subjects not being interesting and fun in the higher grades (Turner & Ireson 2010:130), science subjects being viewed negatively (Hillman et al. 2016:204), the beliefs and values that learners hold regarding science subjects (Fasasi 2017:551), as well as the teaching style of science teachers. These may all have contributed to science subjects seeming more difficult (Hampden-Thompson & Bennett 2013:1327; Wan & Lee 2017:508;

Mujtaba et al. 2018:645) than they actually are, which may have negatively influenced learners' attitudes leading to the decline.

This view is buttressed by the study carried out by Fernández Cezar and Solano Pinto (2017:119) in Spanish schools, in which they also found the same trend. This may be attributed to the interests and academic achievements of the learners in science being determined by their attitudes (Aslan 2017:1) towards science.

Similar research carried out by Reddy (2017:26), in South Africa, also shows that learners' declining interest in science may be influenced by their attitudes towards science, perceived difficulty of science subjects and the quality of teaching. Moreover, research has shown that learners with positive attitudes towards science tend to perform better in science subjects (Chi et al. 2017:2127). Numerous studies have also pointed to the need for more active pedagogies in order to halt the steady decline in the interest of learners towards science (Toma et al. 2019:509).

Also significant from the literature is the observation by Oon et al. (2020:90) that learners' perception of their teachers may also influence their attitudes. The quality of the teachers' instruction may influence learners' engagement with the content. The learners also enjoy the lessons of teachers who promote an active learning environment through their use of variety of teaching tools and teaching styles that enhance learner cognition (Sasway & Kelly 2020:14).

3.2.3 The relationships between various constructs related to natural sciences learning and attitudes change

3.2.3.1 Personal interest

Personal interest is conceptualised as learners' desire to understand a topic that persists over time. This desire increases their engagement in learning and knowledge acquisition (Sørebø & Hæhre 2012:350) and might influence their attitude towards the subject. Personal interest plays an important role in motivating learners to do their best, as it provides a much-needed boost (Afzal Humayon, Raza, Aamir Khan & Ansari 2018:134) for their persistence in carrying out a task, because it carries both cognitive and affective components. Personal interest is therefore an outcome variable that is additionally decisive for the development of other outcome variables, such as scientific literacy (Hoft, Bernholt, Blankenburg & Winberg 2018:186).

The application of puppetry art as a teaching tool to teach ecology might influence learners' personal interests and a possible attitude change towards natural sciences. According to Phan and Ngu (2018:56), "personal interest is likely to mobilize various psychological processes, such as an increase in effort expenditure, a high level of persistence, and/or engagement of deep cognitive strategies". In view of the above scholars' perspective on the role of personal interest in cognition, it therefore suggests that learners' personal interest in the subject might provoke the development of positive attitudes towards natural sciences, which in turn may positively influence their academic achievement. Phan and Ngu (2018:57) further found that a learner's positive evaluation of his/her ability in a specific subject area influences their academic achievement. This might also influence a change in attitude towards the subject.

3.2.3.2 Conceptual and applied conceptual understanding

Conceptual understanding is very important for science education which is conceptualised in terms of learners' understanding of concepts (Hoft et al. 2018:188), specifically in the case of natural sciences. It is a learning process in which relationships and similarities between concepts can be demonstrated in a transferable way to facilitate learners' application of what they have learnt in terms of real-life problem solving (Macanas & Rogayan 2019:207). This is the case because new knowledge is constructed as learners gather and interpret data and engage in problem-solving through their interaction with puppets. Therefore, the way learners conceptualise the purpose and scope of learning, determines the value and scope they place on it, as well as their attitude towards it (Slade & Downer 2019:531).

Memorising concepts will not increase the science processing skills of learners, but the freedom to probe and investigate through the application of conceptual understanding in learning will (Macanas & Rogayan 2019:207). The constructivist view of learning posits that the growth of understanding involves a learner constructing his or her own understanding of knowledge (Mi, Lu & Bi, 2020:551). Developing conceptual understanding is a process, and in this process an in-depth understanding is realised by structuring the relevant concepts (Aydin Ceran & Ates 2020:150). This may be facilitated through the application of puppetry art as a teaching tool, which might also influence a change in learner attitudes towards natural sciences.

3.2.3.3 Sense-making

Sense-making has been conceptualised as a stance or approach that learners adopt towards science learning. It can be defined as a dynamic process of building an explanation in order to resolve a gap or inconsistency in knowledge (Odden & Russ 2018:199) of natural sciences concepts. It is also a type of cognitive process, because during sense-making learners fit new knowledge into their existing knowledge framework, which are built out of ideas that they have learnt from their experiences (Odden & Russ 2018:194) with puppetry art as a teaching tool. It therefore involves a mix of formal and prior knowledge.

The application of puppetry art as a mediatory artefact (teaching tool) in the teaching and learning of natural sciences might influence learners' sense-making of natural science knowledge, which might lead to a change in attitude towards the subject. According to Strike and Perup (2016:881), mediated sense-making is a process through which the mediator (puppetry art as a teaching tool) brings forward points of view to generate, pause, doubt and inspire inquiry among learners who are practicing sense-making within a bounded context. Sense-making can therefore be said to be a form of learning which involves the learners “figuring out things” for themselves, because the sense learners make of a subject influences how they will act (Strike & Perup 2016:882; Odden & Russ 2018:198) towards the subject.

In mediated sense-making, the mediator (puppetry art as a teaching tool) helps the sense makers (learners) to think differently about the sense that has already been made (regarding natural science knowledge) by regulating the pace of meaning-making and catalysing attention to particular cues (Strike & Perup 2016:882). When a group of learners are exploring natural science content through the application of puppetry art as a teaching and learning tool, it involves embodied knowledge and communication with one another. Di Paolo and Thompson (2017:75) describe this as participatory sense-making, which infers that the sense-making effort can be shared among the learners. It can therefore be experienced to various degrees, including joint sense-making, where learners can experience knowledge construction that would not have been possible on their own.

Scholars have also identified three key aspects of sense-making as (a) perceiving cues – which might involve character and context, (b) extraction and reflection – which can be said to be creating interpretation of those cues, and (c) acceptance and adaptation – which involves acting on those interpretations (Heaphy 2017:644; Coetzee & Wilkinson 2020:34). From the perspective of the above scholars, one can see that the sense that learners make of natural science knowledge mediated by the application of puppetry art as a teaching tool might improve their self-efficacy in the subject, which again might influence a change in attitude towards natural sciences.

In view of the research outcomes on the influence of sense-making (Heaphy 2017:644) on learners' learning, the application of puppetry art as a teaching tool might positively influence learners' sense-making of natural science knowledge. This might influence their reflections on the knowledge acquired and might lead to their acceptance and adaptation of the acquired knowledge. This might in turn influence an attitude change towards the subject.

3.2.3.4 General problem-solving confidence and sophistication

Problem-solving is a critical skill for learners to develop in order to cope with learning. It encompasses other skills such as reasoning and discretion (Palavan 2017:188). The application of puppetry art as a teaching and learning tool in natural sciences might enhance the problem-solving confidence of learners, which might influence an attitude change towards the subject. This can be attributed to the enhancement of learners' bodies and minds through problem-solving and self-confidence skills (Palavan 2017:189).

According to Palavan (2017:188), the use of drama (puppetry art) as a teaching tool is a promising technique that may address both learners' self-confidence and problem-solving abilities. Drama (puppetry art) may allow learners to have experiences that might enable them to develop self-confidence in order to trust others and work co-operatively with them (Palavan 2017:189).

Drama (puppetry art), in contrast with traditional teacher-centred methods, exposes learners' imagination and enables a learner-centred setting, and is almost a revolutionary technique for knowledge acquisition (Wagner 2005:11). Problem-solving therefore is a crucial skill that may enable learners to develop self-confidence and other personal skills necessary to tackle problems in real-life settings which drama (puppetry art) as a teaching tool will help them to build (Palavan 2017:189).

The implication of this is that learners' ability to succeed, as well as their success levels, improves as their problem-solving confidence increases (Palavan 2017:189). The application of drama (puppetry art) in education therefore indirectly improves the problem-solving skills of learners solely by increasing their self-confidence. This is so because an increase in self-confidence levels may lead to an increase in problem-solving skills (Palavan 2017:190). In the context of the study's objective, therefore this might influence a change in attitude by learners towards natural sciences.

3.2.3.5 Real-world connection

Real-world connection can be defined as the connection between the subject (natural science) content taught in the classroom and the outside world (Mosvold 2008:3). It can also be a general term for simple analogies, the discussion of subjects (natural science) in society, hands-on representation of natural science concepts, and the modelling of real phenomena (Gainsburg 2008:200).

The application of puppetry art as a teaching tool to teach ecology in natural sciences might help learners to connect their knowledge of ecology to real-world situations, which might influence their attitude towards the subject. According to Didiş-Kabar (2018:267), a real-world connection has the advantage of fostering learners' understanding of the subject, constructing learners' knowledge and motivating their learning. The use of real-world problems in science lessons is most likely to provide learners with various benefits, especially in the cognitive sense (Didiş-Kabar 2018:267), such as helping them to comprehend concepts more easily.

Real-world connections help to improve learners' motivation and interest in the subject, as well as their positive attitude towards the subject (Karakoç & Alacacı 2015:38). Making real-world connections can contribute to improving learners' general performance and achievement in the subject. It can also provide an opportunity for improving learners' problem-solving and analytical thinking skills, since it provides the learners with an environment where they can develop multiple approaches to problem-solving (Karakoç & Alacacı 2015:41). This might be facilitated by the application of puppetry art as a teaching tool to teach ecology in natural sciences, which may enable learners to interpret ecological concepts and relate them to each other and to the real world. Real-world connections with the subject content are often cited as helping to raise learners' motivation (Karakoç & Alacacı 2015:33).

In the next section, the researcher will discuss teachers' attitudes towards science, and its implications in the teaching and learning of natural sciences.

3.2.4 Teachers' attitudes towards science

The teachers are the key implementers of any new teaching approach. Their beliefs about teaching science influences their attitudes and classroom practices (Jamil et al. 2017:2). The teachers' attitudes towards science are important, as they influence their teaching styles and affect learners' interests, attitudes and achievement in science (Ualesi & Ward 2018:35). Moreover, the science teacher's personality and attitude directly impact on learners' interest and attitudes towards science (Hassan 2018:2045; Oon et al. 2020:91).
This is evidenced by the quality of their teaching practices. Teachers with negative attitudes tend to spend less time on teaching. They rely more on planning by other teachers, have low self-efficacy beliefs and low self-confidence, all of which play a significant role in determining the attitudes of their learners towards science (Osborne et al. 2003:1068).

For learners to develop positive attitudes towards science, teachers need to have the capacity to use different new methods of teaching, have positive views about science and also have positive attitudes (Ambusaidi & Al-Farei 2017:72). Teachers with a strong sense of self-efficacy and confidence about teaching science tend to have more positive attitudes (Ualesi & Ward 2018:44).

Research has shown that teachers will develop positive feelings and attitudes if they have access to the necessary equipment and tools needed for effective teaching practices, including adequate teaching tools (Ualesi & Ward 2018:45). This is because teaching must address learners' thoughts, feelings, values and actions towards science (Hassan 2018:2046). The quality of educational resources and instructional materials will therefore significantly contribute to teachers 'positive attitudes towards science (Hacieminoglu 2019:77).

The lack of confidence and insufficient knowledge to teach science by many of the teachers may be traced to their primary and secondary school education (Van Aalderen–Smeets et al. 2012:159). It may not have offered them the necessary opportunities for self-development (Ambusaidi & Al-Farei 2017:74; Pino-Pasternak

& Volet 2018:1521). This may have led to low self-efficacy and the development of negative attitudes towards science (Hassan 2018:2045), which may negatively impact their teaching practices (Karamustafaoglu & Bayar 2018:125; Oon et al. 2020:92).

Teachers' self-efficacy, as reported by scholars, comprises the evaluative thoughts and beliefs they may hold regarding their ability to teach science. This has been found to significantly contribute to shaping their behaviour towards science (Van Aalderen–Smeets et al. 2012:175; Van Aalderen-Smeets & Van der Molen 2013:578:580; Aldahmash et al. 2019:5).

Negative self-efficacy may lead to the teachers focussing more on didactic modes of teaching, as stated earlier, thereby compromising the quality of their teaching practices and the attitudes of their learners towards science (Appleton & Kindt 1999:160; Osborne et al. 2003:1068; Villafuerte et al. 2015:477; Van Aalderen–Smeets et al. 2017: 240; Sasway & Kelly 2020:3). Research has also revealed that science teachers may have an influence on the ability of their learners to find relevance, build confidence, and maintain positive attitudes in the learning process (Sasway & Kelly 2020:13).

The individual teachers' self-efficacy contributes to the educational experience of the learners, as well as their positive attitudes towards science (ibid.). Moreover, the teachers' beliefs about their potential for success translates to their own self-efficacy (Sasway & Kelly 2020:15) and determines how they teach.

In a study carried out by Verdugo-Perona, Solaz-Portolés and Sanjosé-López (2016:791), in which they determined the relationship between attitudes and conceptual or procedural knowledge in science, they found that teachers who integrated the cognitive and emotional components of attitudes, gave more reliable answers. Researchers therefore concur that improving the cognitive and normative determinants of teachers' attitudes towards science is important in promoting learners' positive attitude towards science (Van Aalderen-Smeets & Van der Molen 2013:578; Van Aalderen-Smeets et al. 2017:240). This is an indication that teachers' attitudes towards teaching science, and how they teach science, may have a profound impact on learner attitudes towards science (Fernández Cezar & Solano Pinto 2017:114; Van Aalderen–Smeets et al. 2017:239; Sasway & Kelly 2020:15) and how they learn.

From the above literature, the researcher was able to establish the relationship between, and determining effects of, learners' and teachers' attitudes and their interest in science.

In the next section, the researcher will discuss how the three determinants of attitudes fit into the study. Each of the determinants will be examined within the context of their relevance to the study, and how they are influenced using puppetry art as a teaching tool to create space and opportunity for attitude change.

3.2.5 Cognitive beliefs of teachers and learners towards natural sciences

According to Pongsophon and Herman (2017:3), cognition defines the beliefs and opinions of the teachers and learners regarding the relevance of natural science teaching and learning. It also relates to the perceived difficulty in natural science teaching and learning.

The component of cognition (see figure 3.1) is relevant to this study. It provides insight into the extent to which the teachers and learners may think that natural sciences is not relevant in their career development (Van Aalderen–Smeets & Van der Molen 2013:580), which may inform their negative attitudes. Secondly, their beliefs regarding the perceived difficulty of natural sciences, are further relevant as it informs their negative attitudes towards natural science teaching and learning, respectively (Van Aalderen–Smeets et al. 2017:242).

The teachers' lack of self-confidence and familiarity with natural science content may also influence their perception of the subject as being difficult. This may force them to focus on the didactic mode of teaching, which may negatively influence their attitudes and the quality of their classroom practices, as well as the attitudes of their learners (Osborne et al. 2003:1068; Van Aalderen–Smeets et al. 2012:169; Wan & Lee 2017:508; Aldahmash et al. 2019:5; Oon et al. 2020:92).

According to Ajzen and Sheikh (2013:155), the beliefs about how relevant or difficult natural sciences is can be explained in terms of learner engagement with the content due to the teachers' use of strategies and tools designed to enhance their understanding. Their participation in the learning activities, as well as learners' good interaction with teachers (Yung et al. 2013:2451) signifies the relevance of learning activities and puppetry art.

3.2.6 Subjective norm beliefs as levels of enjoyment or feelings of anxiety during natural sciences lessons

Subjective norms, or affect refer to the level of enjoyment of natural science teaching and learning by the teachers and learners (see figure 3.1). It also reflects the level of enjoyment and feelings of anxiety associated with natural sciences lessons (Van Aalderen–Smeets et al. 2012: 167; Van Aalderen-Smeets & Van der Molen 2013:580; Van Aalderen-Smeets et al. 2017:242).

The subjective norm component is relevant to the study. If the teachers and learners do not enjoy taking part in the various natural sciences-related activities such as teaching, practical activities, experiments and investigations, it may negatively influence their attitudes towards the subject (Van Aalderen–Smeets et al. 2012:167; Van Aalderen-Smeets & Van der Molen 2013:584; Chi et al. 2017:2127).

Negative feelings of fear and anxiety, such as being tense or nervous during natural sciences lessons or activities (Van Aalderen–Smeets et al. 2012:168; Van Aalderen-Smeets & Van der Molen 2013:581), may also contribute to the development of negative attitudes towards the subject. This may negatively influence the learning and teaching of natural sciences (Pongsophon & Herman 2017:3, Van Aalderen–Smeets et al. 2017:242; Aldahmash et al. 2019:5).

Teachers’ positive attitudes and the use of appropriate instructional scaffolds are essential in the teaching and learning of natural sciences (Blummer 2015:6). It enables the learners to easily construct natural sciences knowledge and overcome the fears and anxiety that lead to negative attitude formation (Lindquist et al. 2017:91; Sasway & Kelly 2020:2).

The subjective norm is one of the components that determine and shape learners’ and teachers’ attitudes towards natural sciences (Reddy 2017:28). A teacher’s enjoyment of the lessons or feelings of anxiety may positively or negatively impact his/her teaching practices (Ambusaidi & Al-Farei 2017:72) as well as learners’ attitudes.

3.2.7 Teachers’ and learners’ self-efficacy and perceived dependency on contextual factors constitute their behavioural control beliefs

Behavioural control beliefs define the degree of control that teachers and learners perceive themselves to have over the teaching and learning of natural sciences (Van Aalderen–Smeets et al. 2012:168). It largely encapsulates the teachers’ and learners’ self-efficacy in natural sciences. Self-efficacy refers to teachers’ perceived capacity to teach as well as the perceived dependency on contextual factors such as the availability of standardised teaching and learning aids or resources (Van Aalderen–Smeets et al. 2017:242; Reddy 2017:29).

The behavioural control beliefs determinant is also relevant. In the context of this study it can be examined in the light of teachers’ perceived lack of confidence in the teaching of natural sciences. This may negatively influence their attitudes towards the teaching and learning of the subject (Yung et al. 2013:2452).

It may also influence the development of negative attitudes in the learners. Moreover, teachers’ dependence on standardised materials, owing to their inability to teach natural sciences without help from colleagues (Van Aalderen–Smeets et al. 2017:242), may also influence their negative attitudes towards teaching the subject.

In the next section, the researcher will discuss the conceptual framework that underpins the study. This is based on the review of the existing literature on prior research on the role of the attitudes of teachers and learners in the teaching and learning of science. Ajzen's theory of planned behaviour, TPB, will be employed to conceptualise how attitudes impact the teaching and learning of natural sciences, and how puppetry art may be applied as a teaching tool for attitude change within the context of the STEAM educational approach.

3.3 The conceptual framework

The research problems that necessitated the study focused on the declining attitudes of learners towards science which have been reported by many scholars (Appleton & Kindt 1999:160; Osborne et al. 2003:1053, 1068; Villafuerte et al. 2015:477; Fasasi 2017:551; Wan & Lee 2017:508; Van Aalderen–Smeets et al. 2017:240; Ualesi & Ward 2018:35; Mujtaba et al. 2018:645; Sasway & Kelly 2020:3; Oon et al. 2020:91). Some of the scholars have researched the causes of declining learner attitudes towards science. These include Barmby and Kind (2008:1078), who in their study in the United Kingdom, attributed the decline to learners' consistent lack of interest in science. Abell et al. (2009:79) found that a lack of effective teaching strategies further contributed to the decline. Schmidt (2011:411) also found that traditional teaching and learning approaches were the source of the decline. Anderson, Anderson, Varank-Martin, Romagnano, Bielenberg, Flory and Whitworth (in Rollnick, Dlamini & Bradley, 2015:1203), attributed the decline to the learners' inability to apply scientific knowledge due to traditional and ineffective teaching methods. Kim and Kim (2016:1910), on the other hand, relates it to a lack of teaching competencies. The common denominator in the declining attitudes of learners towards science, according to the scholars, can be summarised as the learners' lack of interest in the subject due to traditional and ineffective teaching methods.

In their contributions toward addressing the decline, Braund et al. (2013:12) highlighted the importance of the effective integration of the arts as a teaching approach in science. They found that this would provide opportunities for learners to development positive attitudes towards the subject. Sousa and Pilecki (2013:29) also added that due to the creativity inherent in the arts, it might be effectively utilised in the learning of science. Other scholars, including Kim and Chae (2016:1928), Turkka et al. (2017:1403), Tsurusaki et al. (2017:269) and Vennix et al. (2018:1265), stressed that the arts will enhance learners' active learning in science because it will provide hands-on activities targeted at understanding and viewing science differently.

In view of the above reviewed literature on the problems that necessitated the study, and the possible solution offered by the integration of the arts into science teaching and learning, the theory of planned behaviour will be applied as a conceptual framework to conceptualise the integration of puppetry art as a tool for the teaching and learning of natural sciences within the context of the STEAM educational approach (Ajzen 2011:1113).

This theory was introduced in 1985 as a model for the prediction of human social behaviour (Ajzen 2011:1112). It has widely been cited in research papers. From 22 citations in 1985, the number of citations per year grew to 4550 in 2010 (Ajzen 2011:1113). It has also been well documented and widely applied in the field of general education (Yan & Sin 2015:208). A study with teachers in Hong Kong concluded that the theory of planned behaviour (TPB) is a sound framework for understanding teachers' behavioural intentions (attitudes) towards inclusive education (Yan & Sin 2015:209).

Ajzen's theory of planned behaviour provides a framework for the explanation of a wide variety of behavioural intentions (attitudes) and actions (Ajzen 2011:1113). The theory also provides a framework for exploring the relationships between attitudes towards behaviour, subjective norms and perceived behavioural control (Yan & Sin 2015:207). This approach postulates that teachers' and learners' attitudes towards natural sciences are shaped by three types of beliefs: beliefs about the likely consequences of teaching and learning of natural sciences (cognitive beliefs), beliefs about the subjective affective/feelings (normative beliefs), and beliefs about the presence of contextual factors that may facilitate or impede the teaching and learning of natural sciences (behavioural control beliefs) as illustrated in figure 3.2 (Ajzen 2019:1).

The theory of planned behaviour, TPB, therefore, is concerned primarily with behaviours that are goal-directed and steered by conscious self-regulatory processes (Ajzen 2011:1116). Accordingly, the primary determinants of behaviour are the learners' and teachers' behavioural intentions (Yan & Sin 2015:207; Kelani & Gado 2018:83), which are influenced by their underlying beliefs about the subject. In the context of the study, the theory of planned behaviour, TPB, will be applied to:

(a) Conceptualise and explain the effects of the learners' attitudes towards the learning of natural sciences, as well as the influence of the cognitive, subjective norms and perceptions of behavioural control beliefs (see figure 3.2) (Ajzen 2019:1).
(b) Investigate how puppetry art will be applied as a teaching tool to inform the development of new beliefs at the cognitive, subjective norm and perceived behavioural control determinants of attitudes. This is aimed at an attitude change towards natural sciences (see figure 3.2).

Ajzen's theory of planned behaviour has been the target of much criticism and debate (Ajzen 2011:1113). Most critics however accept the theory's basic assumptions but question its sufficiency and inquire into its limiting conditions. The focus of the theory of planned behaviour has often been misinterpreted to mean that the theory posits an impassionate rational actor who reviews all information in an unbiased fashion to arrive at a behavioural decision (Ajzen 2011:1116).

3.3.1 Constructs of the theory of planned behaviour (TPB) and how they relate to the use of puppetry art as a teaching tool for attitude change

The theory of planned behaviour (TPB) consists of the following constructs:

(a) Cognitive beliefs (see figure 3.2): these represent one of the determinants of the learners' attitudes towards natural science. They are the beliefs and opinions of the learners about the relevance of natural sciences, as well as how difficult they perceive the subject to be.

The use of puppetry art as a teaching tool in natural sciences may therefore promote a positive attitude by learners through instructional scaffolding (Sousa & Pilecki 2013:75; Lindquist et al. 2017:92), which may ease the perceived difficulty in learning natural science concepts (Hassan 2018:2046). According to Ajzen (2019:5), the use of puppetry art as a teaching tool in natural sciences might also introduce new beliefs about the relevance of natural science learning, which might address the perceived difficulty in natural science learning and help to shape learners' attitudes towards the subject.

(b) Normative beliefs (see figure 3.2): these are also one of the determinants of learners' attitudes towards natural sciences. They describe the level of enjoyment or feelings of anxiety that learners may experience during natural science lessons (Mujtaba et al.2018:646). The use of puppetry art as a teaching and learning tool might introduce new beliefs about how learners view their enjoyment of natural science lessons, as well as addressing their anxiety related to the learning of natural sciences (Ajzen 2019:4). This might also have a profound influence on their attitudes towards the subject.

(c) Behavioural control beliefs (see figure 3.2): as one of the determinants of learners' attitudes, behavioural control beliefs determine the level of control that learners perceive themselves to have over the learning of natural sciences. It is associated with learners' self-efficacy in the subject (Ajzen

2019:5). The use of puppetry art as a teaching and learning tool in natural sciences might introduce new beliefs which might address the low self-efficacy of the learners in the learning of natural sciences. This may also have an influence on their attitudes towards the subject.

(d) Intention (see figure 3.2): the intention of using puppetry art as a teaching tool is to change learners' beliefs about natural sciences by introducing new beliefs which might facilitate the development of positive attitudes. Since attitudes are assumed to be based on the corresponding set of beliefs (e.g. cognitive, normative and behavioural control), behavioural interventions must try to change those beliefs by introducing new beliefs that, according to the theory of planned behaviour, might ultimately guide the development of positive attitudes (Ajzen 2011:1116) towards the subject.

(e) Actual behavioural control (see figure 3.2): this entails the use of puppetry art as a teaching tool to introduce new beliefs which might lead to an attitude change of learners towards natural sciences. The application of puppetry art as a teaching tool might enable inspiration and introduce a level of novelty. It may also aid in the development of cognitive and social growth (Sousa & Pilecki 2013:29), which may enhance creativity, reduce stress and make natural science lessons more enjoyable (Sousa & Pilecki 2013:29).
The use of puppetry art as a teaching tool is targeted at making the abstract concepts in natural science learning more concrete (De Beer 2015:1). Creating puppetry art–integrated lesson plans in natural sciences might innately promote collaborative culture and creativity, which might further promote the learning experience of the learners (Liao 2019:38). According to Ajzen (2019:4), it is easier to produce a change in the attitudes of learners by introducing interventions designed to lead to the formation of new beliefs than it is to change existing beliefs.
In order to introduce new beliefs, and influence attitude change, the strength of learners' old beliefs may hold, should it be "attacked" through

approaches designed to lead to the formation of new beliefs (Ajzen 2019:4). Given a sufficient degree of actual behavioural control, puppetry art might be used as a teaching tool to “attack” the strength of learners’ old beliefs and change their beliefs regarding natural sciences (Ajzen 2019:1). This might lead to the development of positive attitudes, which is the desired outcome of this study.

(f) Behavioural outcomes (see figure 3.2): the anticipated behavioural outcome of the integration of puppetry art as a teaching tool in natural sciences is the achievement of learners’ positive attitudes towards the subject. The arts have the power to help learners draw on curiosity, observe accurately, think spatially, perceive aesthetically and work effectively with others (Sousa & Pilecki 2013:11).

It has been found to increase the scientific efficacy and creativity of the learners. It might also help to maximise their interest and motivation in science, which might help to improve their scientific competitiveness (Kim & Chae 2016:1927). This might enable them to develop new belief systems at the cognitive, normative and behavioural control levels, leading to the development of positive attitudes in the subject.

Figure 3.2 below illustrates how the use of puppetry art as a teaching tool connects to the constructs of the theory of planned behaviour namely. These are cognitive beliefs, subjective norm beliefs, perceived behavioural control beliefs, intention, actual behavioural control and behavioural outcome. Its application to the teaching of natural sciences has the capacity to alter learners’ old belief systems concerning natural sciences. It also gives the details of how the constructs of cognitive, normative, and behavioural control beliefs might influence learners’ attitudes towards natural sciences.

It further explains how puppetry art might be applied as a teaching tool within the context of the STEAM educational approach to gain enough control over the learners’ beliefs in natural science teaching and learning. This might lead to the desired intention of change in learners' beliefs regarding the learning of natural sciences, which might lead to the achievement of the intended behavioural outcome of the development of positive attitudes towards the subject (Hassan 2018:2046).

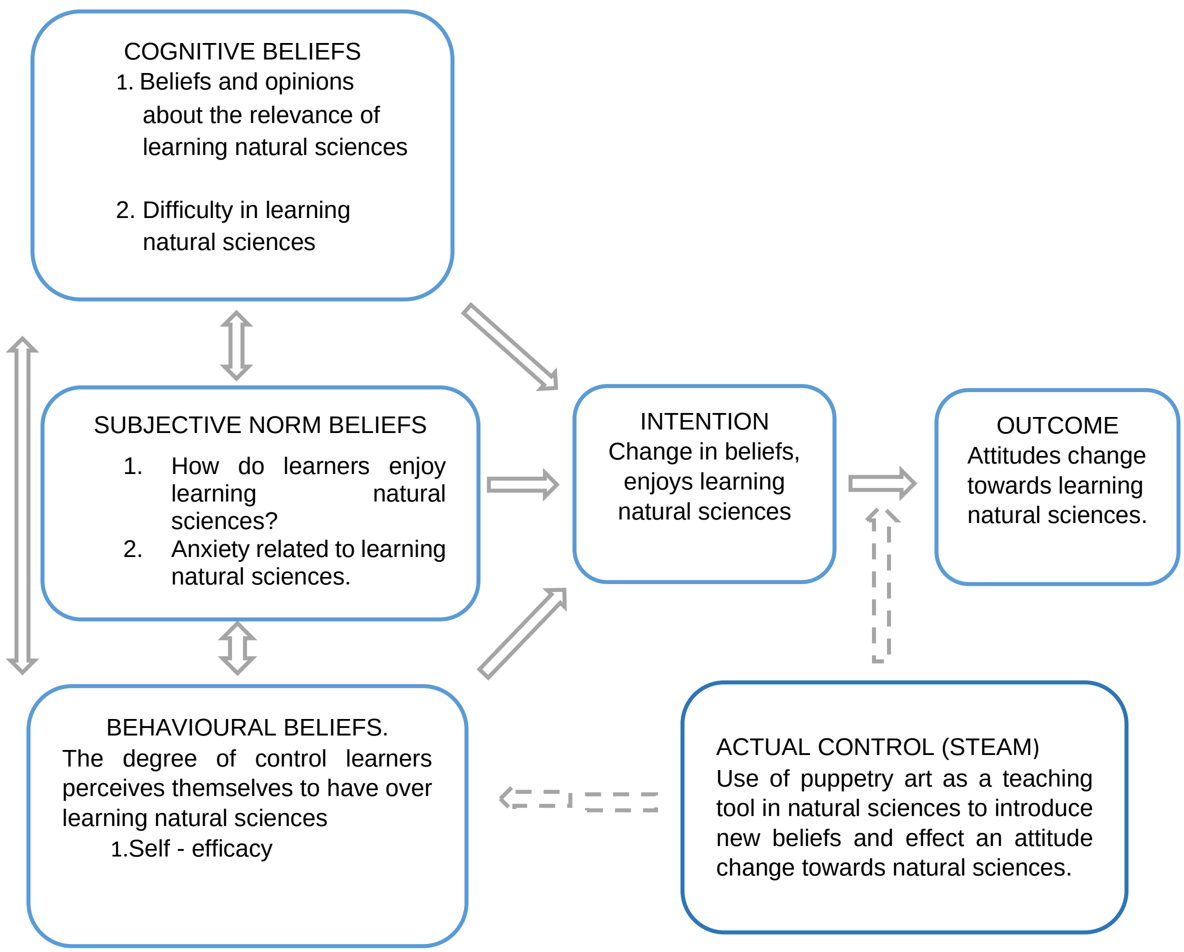

Figure 3.2 Conceptual framework on learners' attitudes towards natural sciences (Ajzen 2019:1).

The main purpose of this study is to determine how puppetry art could be integrated as a teaching tool to influence a change in learners' behavioural intentions towards natural sciences. This would be achieved by introducing new beliefs in the cognitive, normative, and behavioural determinants of attitudes. This is aimed at changing learners' belief systems in natural sciences (see figure 3.2), which might bring about a change in their attitudes towards the subject (Van Aalderen–Smeets & Van der Molen 2013:581; Gado 2018:84; Ajzen 2019:1). The theory of planned behaviour (TPB) provided the conceptual framework to explain how puppetry art would be effectively integrated as a teaching tool in natural sciences. According to the theory of planned behaviour, the strength of the behavioural intentions (attitudes) is predicted by the three main determinants of attitude, namely cognition, subjective norm and behavioural control beliefs (Ajzen 1991:182; Ajzen 2011: 1113; Ajzen 2019:1).

The behavioural intentions are the direct consequence of the three determinants and not a separate component (Van Aalderen–Smeets et al. 2012:175; Aldahmash et al. 2019:5). This implies that the learners' attitudes towards natural sciences are a strong predictor of their behavioural intentions, and their behavioural intentions are the antecedent of their actual behaviour (Van Aalderen–Smeets & Van der Molen 2013:578) towards the learning of natural sciences.

3.3.2 Theoretical underpinnings on the significance of the experimental stimulus to the experimental groups

The researcher's intervention of the experimental treatment to the experimental groups (e.g. being taught ecology with the aid of puppets) during the data collection procedure can be explained in terms of its underlying theoretical underpinnings. In theory, one of the learning approaches that might be applied to address the shortcomings of traditional rote learning methods is the use of the arts to make the teaching and learning of natural sciences more meaningful (Sousa & Pilecki 2013:31).

The application of puppetry art in the teaching of ecology to the experimental groups therefore may increase their motivation to learn. This is because puppetry art promotes creativity (Sousa & Pilecki 2013:24). Its application as a teaching and learning tool may ease the perceived difficulty in learning ecology concepts (Hassan 2018:2046) and promote attitude changes (Sousa & Pilecki 2013:75;

Lindquist et al. 2017:92). Creating puppetry art–integrated lesson plans in ecology might therefore promote collaborative culture and creativity, which might further promote the learning experience of the subjects (Liao 2019:38) by reinforcing their attitude change towards natural sciences.

Negative attitudes follow automatically and consistently from the beliefs of the subjects in the experimental groups regarding their ability to learn (Ajzen 2011:1116). Since attitudes are assumed to be based on those corresponding sets of beliefs, behavioural interventions could attempt to change those beliefs by introducing new beliefs that according to the theory of planned behaviour, might ultimately lead to attitude changes (Ajzen 2011:1116) towards natural sciences.

It might be easier to produce change in the attitudes of the subjects in the experimental groups by introducing an intervention designed to lead to the formation of new beliefs than it is to change their existing beliefs (Ajzen 2019:4). Only when the balance in beliefs in all the three major predictors of attitude shifts in the desired direction, can we expect a change in attitudes (Ajzen 2019:4) towards natural sciences. These determinants of attitude have been found by research to shape the attitudes of the learners (Ajzen 2019:5) toward natural sciences. According to Ajzen (2019:4), in order to introduce new beliefs and influence attitude change, the strength of the old beliefs should be “attacked” through approaches designed to lead to the formation of new beliefs.

One of the teaching approaches that might be used to “attack” the strength of existing beliefs leading to the formation of new beliefs, as prescribed by Ajzen (2019:4), might be the use of puppetry art as a teaching tool within the context of the STEAM educational approach. This might lead to the formation of new beliefs at the cognitive, normative, and behavioural levels, thereby influencing the subjects’ attitude change towards natural sciences.

According to Ajzen (2019:5), therefore, the application of puppetry art as a teaching tool to teach ecology to the experimental groups during data collection for this study might produce these possible outcomes in their cognitive, normative and behavioural determinants of attitudes as discussed below:

(a) Cognitive beliefs: the use of puppetry art as a teaching tool to teach ecology in the experimental groups might facilitate the introduction of new beliefs on the perceived relevance of the subject because it introduces a different style of interpersonal relationship which is very productive for science learning (Simon et al. 2008:1231). It also aids instructional scaffolding (Simon *et al.* 2008:1246; Lindquist et al. 2017:92), which has the potential to make a positive impact on the perceived relevance of the subject. This is crucial for the guided construction of knowledge (Simon *et al.* 2008:1246; Belohlawek et al. 2010:36-37).

    This might enable the subjects to have different opportunities for cognitive development in their peer group interactions, due to their exposure to reasoning that is superior to their own (Simon et al. 2008:1241). This might ease the perceived difficulty in learning ecology (Hassan 2018:2046).

(b) Normative beliefs: the use of puppetry art as a teaching tool might introduce new beliefs on enjoying ecology lessons. This can be attributed to the puppets' influence on the subjects' attitudes through their appearance, movement, speech, and action (Ahlcrona 2012:172). The power of the puppets to evoke thoughts, associations, feelings and intentions in their interaction with the subjects during the ecology lesson, and even after the lesson in the form of recollections (Ahlcrona 2012:173), might change their levels of enjoyment of ecology lessons.

    Moreover, the power of the puppets might also have an influence on their affective domain which embodies feelings that can be transformed into an action, a thought or interaction (Sloan 2018:585). This transformation might have a powerful influence (Sloan 2018:584) on how they enjoy ecology lessons by enabling the subjects to easily construct ecology knowledge and overcome their fears and anxiety (Lindquist et al. 2017:91; Sasway & Kelly 2020:2) which prevent them from enjoying ecology lessons. This might also have some profound influence on introducing new beliefs on how they enjoy ecology lessons, resulting in a possible attitude change towards natural sciences.

(c) Behavioural beliefs: the use of puppetry art as a teaching tool in ecology might introduce new beliefs that address the subjects' low self-efficacy. This might enable them to perform communication acts based on knowledge–related and emotional motives, which oversteps the boundaries between actual and imagined worlds (Ahlcrona 2012:180). He described the power of puppets, when applied in the context of the teaching and learning of science, as able to evoke and arouse learners' emotions, thoughts and associations, which might positively impact their attitudes, and also in the form of recollections, which might consolidate their learning (Ahlcrona 2012:173).

This might improve their self-efficacy and make the learning of ecology more interesting and meaningful (McGregor & Knoll 2015:339). Puppets therefore are familiar figures that might influence the imaginary world of the subjects and improve their creativity (Güçlü & Çay 2017:130), leading to the introduction of new beliefs that might address their low self-efficacy and inspire the desired change in their attitudes towards natural sciences.

According to Ajzen's stipulations, the application of puppetry art as a teaching tool to teach ecology to the experimental groups might enable inspiration and novelty as well as the development of cognitive and social growth (Sousa & Pilecki 2013:29). This might enhance creativity, reduce stress and make ecology lessons more enjoyable (Sousa & Pilecki 2013:29). The STEAM educational approach incorporates the arts to enhance science learning through exposing learners to subjective views of the world as a compliment to the objective view offered by science (Sousa & Pilecki 2013:10; Kim & Chae 2016:1928).

The arts also have the power to help the learners to draw on curiosity, observe accurately, think spatially, perceive aesthetically and work effectively with others

(Sousa & Pilecki 2013:11). It has been found to increase the scientific efficacy and creativity of learners. It might also maximise their interest and motivation in science, which might help them to improve their scientific competitiveness (Kim & Chae 2016:1927). This might enable them to develop new belief systems at the cognitive, normative, and behavioural levels leading to an attitude change in natural sciences.

The theory of planned behaviour provides a framework for the conceptual understanding of how the integration of puppetry art as a teaching tool within the STEAM context could be achieved (Ajzen 2011:1113; Hacieminoglu 2019:63; Ajzen 2019:2; Oon et al. 2020:91). It also describes the relationship between the main concepts of the study to promote and systemise the knowledge espoused by the research, as well as how the research problems were explored (Adom, Hussein & Agyem 2018:439).

Although the theory of planned behaviour (Ajzen 1991:182; Ajzen 2011:1113; Ajzen 2019:1) has its shortcomings with respect to the actual prediction of behaviour (Kelani & Gado 2018:84), it provided an appropriate framework for the conceptualisation of the research problems in order to answer the research questions in this study. This research explored the effectiveness of puppetry art as a teaching tool to change learners' attitudes towards natural sciences.

3.4 Conclusion

In this chapter, prior literature on attitudes, and the attitudes of teachers and learners towards the teaching and learning of natural sciences, was reviewed, as well as the conceptual framework that underpins the study. This was done in order to establish the theoretical basis for the argument on the use of puppetry art as a teaching tool for attitude change in natural sciences, as well as to establish a solid conceptual foundation for the study.

Some of the problems identified by the researcher from the reviewed literature include the effects of ineffective teaching approaches and tools in determining the learners' attitudes towards school science as a subject of choice. The learners' accomplishments in school science subjects are greatly influenced by their own as well as their teachers' attitudes. This also affects teachers' classroom practices. The literature also points to the fact that learners' attitudes towards school science subjects have been on the decline over the past number of years.

The researcher was able to establish from the literature that any intervention aimed at improving teachers' and learners' beliefs in the teaching and learning of school science respectively, may improve their interest and attitudes in the subject through the enhancement of their cognitive, normative and behavioural beliefs about the teaching and learning of the subject.

Given the various shortcomings identified from the reviewed literature, the study will attempt to address the identified gaps through the development of accounts on how puppetry art can be integrated into the teaching and learning of natural sciences to promote creativity, and improve the self-efficacy as well as the beliefs of teachers and learners. This will make natural science learning more interesting, attractive and fun for the learners. It will also help in changing the way they view the subject, as well as the development of a positive attitude towards the subject.

In the next chapter, the quantitative research design and methodology employed in the collection of data towards the study of the effectiveness of puppetry art in changing learners' and teacher's attitudes towards the teaching and learning of natural sciences will be discussed. The data towards this study was obtained with the CLASS (Colorado Learning Attitudes about Science Survey) pre- and post-attitude survey. This was administered to both the experimental and control groups of 356 Grade 9 learners from three different schools in the Motheo District of the Free State. The rationale for the choice of the CLASS attitude survey questionnaire as a data collection instrument for the study was data storage and analysis. The ethical considerations for the study will also be discussed.

CHAPTER FOUR

THE RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

In Chapter 3 a review of the relevant literature on the role of positive attitudes in the teaching and learning of natural sciences was made. The conceptual framework that underpins the study was also discussed. In this chapter the research design and methodology, together with its epistemological and ontological underpinnings, will be discussed. The design outlined the processes and procedures for data collection and analysis employed in order to answer the main research questions and sub-questions as outlined in Chapter 1.

As previously stated, the purpose of this research is to determine the effectiveness of using puppetry art as a teaching tool to improve the learners' attitude towards natural sciences. In order to achieve this, the research will focus on the development of an account of how puppetry art can be utilised as an effective teaching tool within the context of the STEAM educational approach. The realisation of this purpose will be guided by the determination of the significance of puppetry art as a teaching tool for attitude change, as well as the formulation of recommendations and/or guidelines on the effective use of puppetry art as a teaching tool in natural sciences.

According to Kothari (2004:32), design is important in research because it helps the researcher to organise his or her ideas about the research. It is as important as the models that the researcher will employ to analyse the resulting data. The type of design employed in the study was determined by the research questions, research objectives and the scope of reference. It was also determined by the limitations as well as the reporting procedures (Kraska 2012:2; Auspung & Hinz 2015:19).

In the next section, the background problems that informed the research questions and the objectives will be discussed.

4.2 The factors that informed the research questions

Research questions involve the examination of the relationship between two or more variables. These relationships can either be expressed as positive or negative correlations, or causal relationships (DeForge 2012:2). According to DeForge (2012:3) causal relationships are underpinned by three main criteria: (a) correlation between the variables, (b) temporal precedence or sequence, and (c) no alternative explanation. The research questions in this study examined the causal relationship between the use of puppetry art as a teaching tool in natural sciences and learners' possible attitude change towards the subject.

According to DeForge's stipulations, there might be a correlation between the use of puppetry art as a teaching tool and the possible attitude change of the learners towards natural sciences, because (a) as the value of one variable changes, the other might also change, (b) the variable considered to be the cause, the use of puppetry art as a teaching tool, precedes the effect variable, the possible attitude change towards natural sciences in time, and (c) the cause and effect relationship between the variables cannot be explained by the presence of another variable.

During the formulation of the research questions, the causal relationship between the variables stated in the research problems was examined. The formulated research questions were therefore strongly linked to the purpose of the study (De Forge 2012:4).

4.2.1 The background problem, research questions and hypothesis

Research outcomes over the years have revealed a significant decline in the number of learners doing science subjects at school. This trend has been observed in many countries across the world, including South Africa (Osborne et al. 2003:1050; Kind et al. 2007:26; Barmby & Kind2008:1078; Kennedy et al. 2014:34; Villafuerte et al. 2015:477; Fernández Cezar & Solano Pinto 2017:112; Reddy 2017:26). The observed indicated a decline that has gone beyond cultural and national boundaries (Hampden-Thompson & Bennett 2013:1326; Kennedy et al. 2014:35; Wan & Lee 2017:509; Toma et al. 2019:509).

Many factors may have contributed to this decline. These include the attitudes of learners towards science, beliefs and values the learners may hold regarding science subjects (Turner & Ireson 2010:130; Hillman et al. 2016:204; Fasasi 2017:551), as well as the teaching tools that science teachers use to engage with the content. These might have resulted in science subjects seeming difficult to the learners (Hampden-Thompson & Bennett 2013:1327; Wan & Lee 2017:508; Mujtaba et al. 2018:645), which might negatively influence learners' attitudes towards the subject. In view of this, some scholars proposed that the application of appropriate instructional tools and a variety of teaching approaches in science lessons (Ambusaidi & Al-Farei 2017:72; Hacieminoglu 2019:79; Sasway & Kelly 2020:2) might help to improve learners' attitudes towards the subject.

Braund et al. (2013:12) suggest the importance of exploring opportunities to develop science teachers in the effective use of drama (art) as a teaching tool in order to develop their skills and improve their attitudes towards science. Numerous studies pointed to the need for more active pedagogies in order to halt the steady decline in the number of learners embracing science subjects (Toma et al. 2019:509). The reviewed literature also indicated that the application of appropriate instructional tools in science lessons might have the capacity to help in improving learners' attitudes towards the subject (Sasway & Kelly 2020:2).

How the learners learn therefore may depend on the approaches, strategies and tools utilised by teachers to engage with the content (Dohn 2016:188). Van Aalderen-Smeets et al. (2017:239) found that learners' attitude towards science and their learning goals in science are strongly influenced by the teachers' own attitudes, as well as the tools or strategies they use to engage with the content.

In view of the above on the role of attitudes in the declining number of learners doing science subjects, the study therefore intends to address the problem through the application of puppetry art as a teaching tool for attitude change in natural sciences within the context of the STEAM educational approach. In order to do this and achieve the objectives, the research questions and sub-questions that guided the choice of the research approach for this study are again outlined below:

4.2.1.1 Can the application of puppetry art as a teaching tool to teach ecology within the context of the STEAM educational approach influence learners' attitudes towards natural sciences? From the first main research question, the following sub-questions were identified:

4.2.1.1.1 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' personal interest category of their attitudes towards the subject?

4.2.1.1.2 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' conceptual and applied conceptual understanding categories of their attitudes towards natural sciences?

4.2.1.1.3 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' sense-making effort category their attitudes towards natural sciences?

4.2.1.1.4 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' general problem-solving confidence and sophistication categories of their attitudes towards natural science?

4.2.1.1.5 Can the application of puppetry art as a teaching tool to teach ecology influence the learners' real-world connection category of their attitudes towards natural sciences?

4.2.1.2 Can a guideline for the integration of puppetry art as a teaching tool in natural sciences be effectively applied within the context of the STEAM educational approach?

Hypothesis

The application of puppetry art as a teaching tool can influence learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication as well as real-world connection categories regarding their attitude towards natural sciences.

The null hypothesis for the sub-questions

The application of puppetry art as a teaching tool to teach ecology has no influence on learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication and real-world connection categories regarding their attitude towards natural sciences.

4.2.2 The research objectives

In view of the above-mentioned questions and sub-questions, this study aims to achieve the following objectives which are aligned to the research questions:

4.2.2.1 To determine if the application of puppetry art as a teaching tool will influence the learners' personal interest category of their attitudes towards the subject.

4.2.2.2 To determine if the application of puppetry art as a teaching tool will influence the learners' conceptual and applied conceptual understanding categories of their attitudes towards the subject.

4.2.2.3 To determine if the application of puppetry art as a teaching tool will influence the learners' sense-making category of their attitudes towards the subject.

4.2.2.4 To determine if the application of puppetry art as a teaching tool will influence the learners' general problem-solving confidence and sophistication categories of their attitudes towards natural sciences.

4.2.2.5 To determine if the application of puppetry art as a teaching tool will influence the learners' real-world connection category of their attitudes towards the subject.

4.2.2.6 To formulate recommendations and/or guidelines for the effective application of puppetry art as a teaching tool in natural sciences within the context of the STEAM educational approach.

In the next section the research design and its philosophical underpinnings in relation to its application in the collection and analysis of data will be discussed.

4.3 The research design

Research design is the plan that provides the logical structure that guides the researcher to address the research problems and answer the research questions (DeForge 2012:2). It is one of the most important components of the research methodology. It emphasises the planning of the methods for collecting the relevant data and the techniques used in their analysis, keeping in view the objectives of the research (DeForge 2012:2). This is because the research objectives determine the type of research to be done (Kothari 2004:32; Mujis 2011:13). The design therefore consists of the plan, structure and strategy that will assist the researcher to collect, analyse and interpret data (Bloomfield & Fisher 2019:27).

The quantitative design is one of the research designs employed in educational research. According to Morgan (2017:4), the key features of this design as employed in the study are the use of deduction to test theories through observation in order to establish causality between the dependent (possible change in learner attitudes towards natural sciences) and the independent (the application of puppetry art as a teaching tool) variables. The procedure for establishing the relationship between variables include the use of predetermined design principles that separate data collection and analysis (Morgan 2017:4). The design also emphasises objectivity through constructs that can be measured, and therefore the results obtained do not depend on beliefs (Morgan 2017:4). Moreover, standardised instruments were used in data collection to ensure objectivity and the generality of the results to a wider population. The research can also be replicated in subsequent studies to ensure its reliability.

4.3.1 The quantitative experimental research design

According to Brown and Melamed (2011:2), experimentation can be viewed as an extension of inquisitiveness, and consequently is as old as curiosity itself. Burns, Grove and Gray (2015:510) define quantitative experimental research design as a formal, objective systematic approach used to describe variables, test relationships between them and examine the cause-and-effect associations between them. It also determines important aspects such as the identifiability and statistical efficiency of parameter estimates (Auspung & Hinz 2015:23).
The application of the quantitative experimental design enabled the researcher to determine causality between the intervention (the use of puppetry art as a teaching tool in natural sciences) and the outcome (the possible attitude change of learners towards the subject) (Bloomfield & Fisher 2019:29). In order to determine the effect of the independent variable (the application of puppetry art as a teaching tool), the researcher ensured that outside effects (confounding effects) of any other variable or phenomena that might have an influence on the dependent variable (the possible attitude change of learners towards natural science) were controlled (Bloomfield & Fisher 2019:28).

This research design is informed by the positivist and post-positivist paradigm (Miller 2011:5). Positivists believe that the world works according to fixed laws of causality, and therefore scientific thinking is used to test theories about these laws, leading in turn to a better understanding of how the world works (Mujis 2011:14). It is underpinned by the assumptions that there is a single truth or reality, objectivity, and deduction (Mujis 2011:14; Jirojwong, Johnson & Welch 2014:362; Bloomfield & Fisher 2019:27).

Positivism emphasises the scientific method of research and has a realist orientation (Kraska 2010:2). Its philosophy is based on independently existing realities that may not have any other alternative explanation. Positivism emphasises the use of empirical inquiry to understand social phenomena (Leung & Shek 2018:2). It advocates the demonstration of internal validity through accurate interpretability, external validity through generalisability, and reliability through consistency and the replicability of the research findings (Leung & Shek 2018:3).

The positivist epistemology further views the researcher and the researched as independent entities. The researcher can therefore study a phenomenon without influencing or being influenced by it (Slevitch 2011:76). This implies that facts can be separated from values, and that the researcher can achieve truth to the extent to which his or her work corresponds to reality (Slevitch 2011:76; Jirojwong et al. 2014:362). This can be done through the careful application of quantitative research methods and the use of standardised measuring instruments (Mujis 2011:14; James & Slater 2017:11). In the positivist epistemology, therefore, science is viewed as empirical rather than metaphysical, meaning that any propositions that cannot be tested and verified are considered to be meaningless (Leung & Shek 2018:2).

Post-positivists accept that it is difficult to observe the world we are part of and remain objective about it. However, the epistemology of post-positivism holds that there is the possibility of the existence of an objective reality that is shaped by our own subjectivity (Mujis 2011:15; Bloomfield & Fisher 2019:27). Therefore, rather than finding the truth, post-positivism advocates the representation of reality as best as the researcher can by using reliable standardised measuring instruments to carry out the research (Bloomfield & Fisher 2019:27).

This implies that the researcher cannot completely detach himself or herself from the research but should rather use tested measuring instruments to ensure objectivity (Mujis 2011:15). The researcher conformed to this stipulation during the study and employed tested and validated measuring instruments to gather data in order to ensure objectivity.

Employing a Quasi - experimental design in the study helped the researcher to control external factors (Mujis 2011:9) that may have influenced the outcomes. The researcher-controlled manipulation of the independent variable (the application of puppetry art as a teaching tool) ensured certainty in the time sequence. Likewise, the problem of extraneous variables influencing the outcome was greatly reduced, because the researcher had control over the environment, which further ensured that fewer extraneous variables were involved (Mujis 2011:11).

The researcher was able to exercise some control through the experimental and control group design (Leung & Shek 2018:3). This helped to limit any extraneous effects that could have influenced the outcome (Bloomfield & Fisher 2019:30). Having full control and randomisation further strengthened the internal validity, which is known as vigour (Bloomfield & Fisher 2019:27). Vigour can be described as the level of control the researcher exerts to prevent the effects of extraneous variables on the test or outcome (Bloomfield & Fisher 2019:28).

The experimental groups were exposed to an intervention, while the control groups were not (Brown & Melamed 2011:3). Afterwards the results of the effect of the intervention was analysed, and inferences and generalisations were applied to the population. The design also employed deduction to test theories in order to establish causality between the variables (Kraska 2010:5). The experimental design can therefore be distinguished from all other types of research design. It is more representative than other types of design because it avoids researcher bias in the selection of subjects (Bloomfield & Fisher 2019:30).

In order to have the confidence to make generalisations about the population, the research design demonstrated reliability as well as internal and external validity. Validity was achieved by the random assignment of the subjects into groups which minimised group differences (Dawes 2012:2) before the application of puppetry art as a teaching tool to the experimental groups. This reduced the potential threats to external validity by dispersing these threats across the groups (Dawes 2012:2).

It also facilitated causal inferences that reduced the threats to internal validity (Dawes 2012:6) because it controlled bias in the selection process and ensured that all groups were equivalent by having the same characteristics (Kraska 2010:5; Mujis 2011:18). This enabled the researcher to know how the groups were assigned as well as the advantage of modelling the selection process accurately (Leung & Shek 2018:3).

The pre- and post-test data collection instrument also had the advantage of minimising threats to internal validity resulting from attrition. The obtained data was used with the analysis of covariance, to increase the power to reject or accept the null hypothesis (Dawes 2012:4). The null hypothesis is the assumption about the relationship between the dependent and independent variables – the possible attitude change of learners towards natural sciences and the application of puppetry art as a teaching tool. It assumes that there is no relationship between the dependent (the possible attitude change of learners towards natural sciences) and the independent variables (the application of puppetry art as a teaching tool) (Bloomfield & Fisher 2019:27). Therefore, by drawing a sample from a known population of Grade 9 learners, measuring the variables and testing them using the analysis of covariance, the null hypothesis can either be accepted or rejected, based on the outcome of the statistical analysis (Bloomfield & Fisher 2019:27).

The researcher carried out the study using a reliable standardised attitude survey instrument, namely the Colorado Learning Attitudes about Science Survey (CLASS), within the positivist and post-positivist paradigm (Mujis 2011:14). The utilisation of the measuring instrument was important because it connected the scientific observations to the explanation of the relationship between the variables

(Eden 2018:2). This is because post-positivism holds that reality is complicated and cannot be understood mechanically (Şahin & Öztürk 2019:302).

Quantitative experimental research has the following advantages, as stipulated by Mujis (2011:10): the researcher has control over external factors, and this ensured that the researcher made a stronger claim to having determined causality, and the researcher could manipulate the administration of the experimental treatment to be certain of the time sequence.

The environment was controlled to ensure that there were as few distractions as possible during the research. The issue of extraneous variables was highly reduced in this study. Extraneous variables are independent variables that are not related to the purpose of the study but may affect the dependent variable (Kothari 2004:34). Having stated the advantages of using an experimental research design as the mode of data collection and analysis, the researcher will now explore some of the shortcomings or limitations of this research design, and how they were mitigated.

The limitations of the design, as stipulated in Mujis (2011:11), include the difficulties the researcher might encounter in trying to realign the selected schools' timetables during normal school hours to facilitate the experimentation, especially when travelling from one school to another. In order to mitigate this problem and prevent the chaotic environment it poses, the researcher negotiated with the selected schools to conduct the study outside of normal school days, i.e. on Saturdays. This was to avoid the disruption of normal classes, and it created an enabling environment. The different selected schools were therefore visited on different Saturdays (from April to September 2019) until the study was completed.

The second limitation includes the allocation of learners to teachers who may not be competent enough to implement the teaching strategy of teaching with the aid of puppets. In order to mitigate this scenario, the researcher was the only person who administered the experimental stimulus (teaching with the aid of puppets to the experimental groups in each of the three selected schools).

The natural science teachers from the various schools played a supporting role during data collection. The teachers assisted the researcher in assigning arbitrary numbers to the learners from which the participants in the various groups were randomly selected. They also assisted in placing the selected learners into their respective groups (experimental or control) and ensured that the learners were orderly during the lessons. This helped to minimise peer to peer chatting and maintained a conducive environment for the study.

The third possible limitation is a situation where a variety of influences that might affect the outcome may occur, such as the influence of peers on each other. This limitation was addressed through the assistance of the individual Grade 9 natural science teachers from the selected schools. They acted in concert as support personnel and helped to maintain discipline and orderliness.

4.3.1.1 The overview of the study

In table 4.1 below, the key features of the quantitative research design (Morgan 2017:4) employed to carry out the study are summarised.

Quantitative research design
Deduction Purposes • Tests theory through experiments • Oriented to causality Procedures • Predetermined design, probability/simple random sampling • Separate data collection and analysis
Objectivity Purposes • Emphasises constructs that can be measured e.g. attitudes • Results do not depend on beliefs Procedures • Researcher cannot influence the outcome of the research • Relies on standardised attitude survey questionnaire
Generality Purposes • Emphasises generalisation and replication of results • Analyses variables Procedures • Uses experimental and statistical controls e.g. experimental and control groups, descriptive statistics, and analysis of covariance to control the influence of confounding variables

Table 4.1 The summary of the key features of the research (Morgan 2017:4).

The key features of the quantitative research design employed by the study as shown in table 4.1 includes deduction, objectivity, and generality. According to Reichertz (2004:159), deduction does not tell us anything new, but are truth conveying. It was applied in the study to test theories in order to establish causality between the dependent (possible attitude change of learners towards natural sciences) and the independent (the application of puppetry art as a teaching tool) variables (Kraska 2010:5). The study employed a predetermined design in data collection and analysis to substantiate or disconfirm understandings derived from existing theories by empirically testing them (Kennedy 2018:50).

Bertram and Christiansen (2014:186) define the construct of objectivity, as mentioned in table 4.1, as the researcher's ability to avoid bias during data collection, interpretation, and the generalisation of the research findings. This can be interpreted as an attempt by the researcher to "detach" or separate himself from the research as much as possible by employing standardised research instruments, such as an attitude survey questionnaire, to carry out the study.

Generality of the study results, as mentioned in table 4.1, implies that the findings of the study can be applied more generally either to groups similar to the one that the researcher studied or in other contexts (Bertram & Christiansen 2014:25). It is also the extent to which the conclusions of the study may be applied beyond the sample population to the whole population of the study. In this study, the research outcome will be generalised to all Grade 9 learners in the 58 schools in the Motheo District of the Free State.

A sample of those learners were selected from the population, which consists of grade 9 learners in all the 58 schools in the Motheo district, and assigned to the experimental and control groups using probability sampling techniques (see figure 4.1). The learners in the experimental groups were given the experimental intervention while the learners in the control groups were not.

The Colorado Learning Attitudes about Science Survey CLASS (see 4.7.1.1) attitude questionnaire instrument, developed by Adams et al. (2006:1), was administered to the two groups as a pre- and post-test. This instrument was used by the researcher because it probes learners' beliefs about science and learning science, and it also distinguished the beliefs of experts from those of novices and learners. Moreover, it is written in clear and concise language, making it possible for use with learners across a wide range of grades (Adams et al. 2006:1). The outcomes of the pre- and post-test between the two groups were statistically analysed using descriptive statistics to determine if there were any statistically significant differences (Alferes 2013:7).

The study also utilised experimental and statistical controls to remove the effect of one or more confounding variables (Van Breukelen 2012:2). The researcher employed a quantitative design in order to have full control. This was important to prevent or minimise any factor that might influence the findings (Bloomfield & Fisher 2019: 27).

4.3.1.2 The overview of the experimental and control group design

The classic experimental design was employed. It incorporated the pre-test and post-test control group design (Kothari 2004:42; Mujis 2011:16). In this type of design, the subjects are placed into two groups, the experimental and control groups. The experimental groups in this study received the experimental intervention, while the control groups did not. Both groups did a pre-test which was used to measure their attitudes before the intervention, and a post-test on the same instrument after the intervention was given to the experimental groups.
This type of design is superior to other types of experimental and control group designs because it avoids extraneous variation resulting from both the passage of time and from non-compatibility of the experimental and control groups (Kothari 2004:42; Leung 2018:3).

4.3.1.2.1 The details of the experimental and control group design

In figure 4.1 below, the researcher outlines the detailed sequence followed in the classic experimental design. It indicates that a pre-test attitude survey was administered to both the experimental and control groups, and that the outcomes were later compared (see figure 4.1). Likewise, the experimental groups were taught ecology in three lessons (balance in the ecosystem, conservation of the ecosystem and feeding relationships) with puppetry art over the course of the data collection exercise. Some of these concepts include the role of habitat loss, loss of species and climate change in the disruption of the balance in an ecosystem, biodiversity and sustainability in the conservation of the ecosystem, as well as food chains and food webs in the feeding relationships amongst organisms in the ecosystem.

The control groups were taught ecology with textbooks and curriculum materials over the same period (see figure 4.1). Afterwards the attitudes of the subjects in both groups were re-measured, using the same instrument (see figure 4.1). Following the post-test, descriptive statistics were applied to analyse the data and also to statistically determine if the experimental intervention had had any effect (Mujis 2011:16). This was done by comparing the change in the dependent variable in the control groups with the change in the dependent variable in the experimental groups.

It is important to note that the use of control groups enabled the researcher to detect any effects of the experimental intervention. If the post-test indicated that the overall level of attitude change towards natural sciences exhibited by the experimental groups increased after the administration of the experimental stimulus, it implies that the experimental intervention was most probably responsible (Babbie 2010:233).

Figure 4.1 below indicates the details of the classic experimental design (Babbie 2010:234) as were applied to this study.

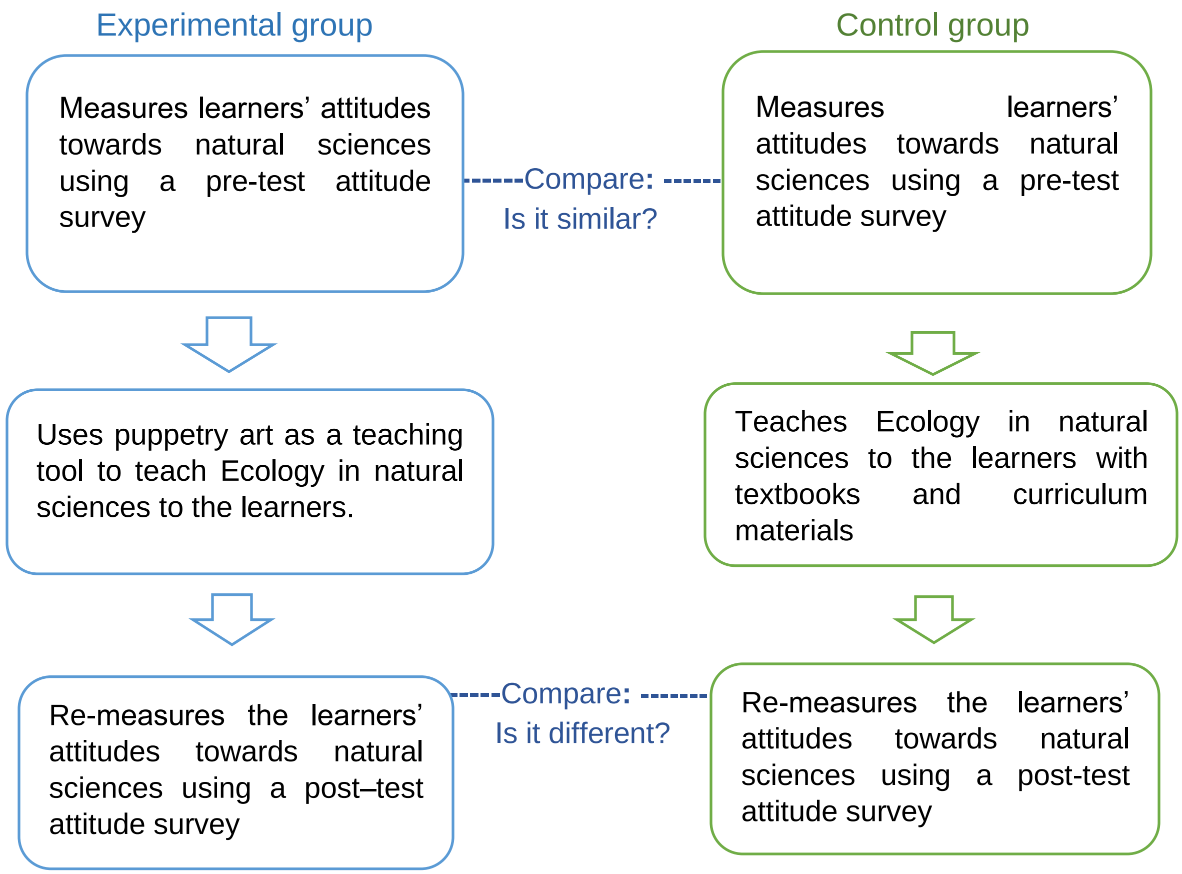

Figure 4.1 Details of the classic experimental design (Babbie 2010:234).

The research methodology and its philosophical underpinnings will be discussed in the next section.

4.4 The research methodology

The research methodology emphasises the individual steps in the research process, and the most objective procedures to be employed during a research project (Major & Savin-Baden 2010:128). It explains the researcher's choice of a specific method or technique and describes the research processes and the type of tools and procedures employed in the research. The research methodology therefore gives details of the type of research design to be implemented, the approaches to measuring variables, and collecting data from the participants. It helps in devising strategies to sample the participants to be studied and planning on how the data collected will be analysed (DeForge 2012:2). These methodological decisions are informed and guided by the type of research design selected by the researcher (DeForge 2012:2).

Another important aspect of the research methodology is that it answers questions relating to why the research has been undertaken, how the research problems have been defined, what data has been collected and why a particular technique of data analysis has been used (Kothari 2004:9). It also focuses on the analysis and interpretation of any numerical data. According to James and Slater (2017:11), the research methodology is the umbrella under which the research methods fit and should be aligned with the epistemology.

4.4.1 The quantitative research methodology

The quantitative research methodology involves the explanation of phenomena through the collection and analysis of numerical data using specific statistical methods (Mujis 2011:12) such as descriptive statistics. This methodology was used to gather and analyse numerical data. This was done in order to establish if there was any statistically significant relationship between the use of puppetry art as a teaching tool and a possible attitude change of learners towards natural sciences. The statistical analysis of the data was aimed at answering the research questions to achieve the research objectives (Ingham–Broomfield 2015:34). This methodology is therefore the most appropriate for a larger population study where the data should be gathered around a relatively small and specific set of topics (James & Slater 2017:7) such as the effectiveness of puppetry art as a teaching tool for attitude change in natural sciences.

Objectivity and generalisability are the underlying methodological principles of the quantitative approach, which is marked by operationalism, i.e. the belief that all theoretical terms can be reduced to observable phenomena (Slevitch 2011:76). This advocates for methods grounded in a statistical approach, with the assumption that a totally unbiased account of the world can be achieved through the careful application of the scientific method (Miller 2011:2). This research philosophy also holds that comprehension of the world is found in the search for causal relationships and universal laws. The universal laws denote the laws of cause-and-effect, which can be tested statistically and be either accepted or rejected (Miller 2011:3).

The ontological and epistemological foundations of the quantitative research methodology suggest the assessment of the quality of the research process through standards of validity (see table 4.2) and reliability of the research findings (Miller 2011:5). This was done through processes aimed at eliminating threats to validity. Various strategies were prescribed to ensure that values and biases did not influence the outcomes (Slevitch 2011:76). These methodological strategies, the random assignment of subjects to groups and random sampling (see table 4.2), were employed to ensure validity in the research process (Miller 2011:5). The research findings can therefore view as ‘true’ or ‘valid’ when these prescribed procedures are rigorously followed (Slevitch 2011:76).

In table 4.2 below, the researcher indicates the methodological strategies employed to ensure internal and external validity of the research findings (Miller 2011:5).

Criteria	Descriptions	Methodological strategies employed by the study to ensure internal and external validity of the results
Internal validity	The extent to which the researcher is sure that no confounding variables have influenced the relationship between the independent and dependent variables.	The random assignment of subjects to the experimental and control groups was employed and the environment was controlled to eliminate the effects of extraneous variables.
External validity	The extent to which the researcher can generalise the results to another context.	It employed random sampling and realistic activities e.g. the use of puppetry art as a teaching tool.

Table 4.2 Methodological strategies employed to ensure internal and external validity of the research findings (Miller 2011:5).

The quantitative research methodology has several unique features which makes it suitable in the collection and analysis of data. These, as outlined in Leung and Shek (2018:3), include the emphasis on the objectivity of the research. Objectivity refers to the assurance that bias and subjectivity were minimised in data collection and analysis. Therefore, a reliable standardised attitude measuring instrument was used during data collection. Secondly, empiricism is stressed in quantitative research. Empiricism means that the research is guided by the evidence obtained from systematic research rather than from authorities.

The third unique feature includes the accuracy and precision of measurements in a study, which are determined by ensuring the reliability and validity of the research. In this study, this was ensured by using one instrument for both the pre- and post-tests. The subjects were also randomly assigned to the various groups (Babbie 2010:241; Leung & Shek 2018:4). Fourthly, logical reasoning is also fundamental to quantitative research. The study therefore relied on empirical methods, having strict rules and clear procedures. Deductive methods were therefore employed. These include making assumptions on the influence of the use of puppetry art on attitude change of learners in natural sciences which was further tested using the pre-and post-tests and finally conclusions were drawn from the results of the test.

Finally, quantification of the results is emphasised by statistical procedures and presentations. The purpose of the research therefore was to establish the relationship between the studied variables (the relationship between the use of puppetry art as a teaching tool and the possible attitude change of the learners). The obtained results were statistically reduced to simple general rules. Replication of the research results is stressed (the results should be confirmed in subsequent research). Thus, representativeness and generalisation of the findings in explaining social phenomena and predicting outcomes are essential.

According to Miller (2011:5), data gathered through quantitative methodology are analysed with statistical methods. The results from this study were therefore statistically analysed using descriptive statistics. This enabled the researcher to compare the outcome of the groups on the experimental treatment with those in the control groups.

Figure 4.2 below, adapted from Alferes (2013:7), outlines the major steps in the collection and analysis of data. The details of each step in the design as outlined in figure 4.2 will be described and fully discussed under specified headings in the next section.

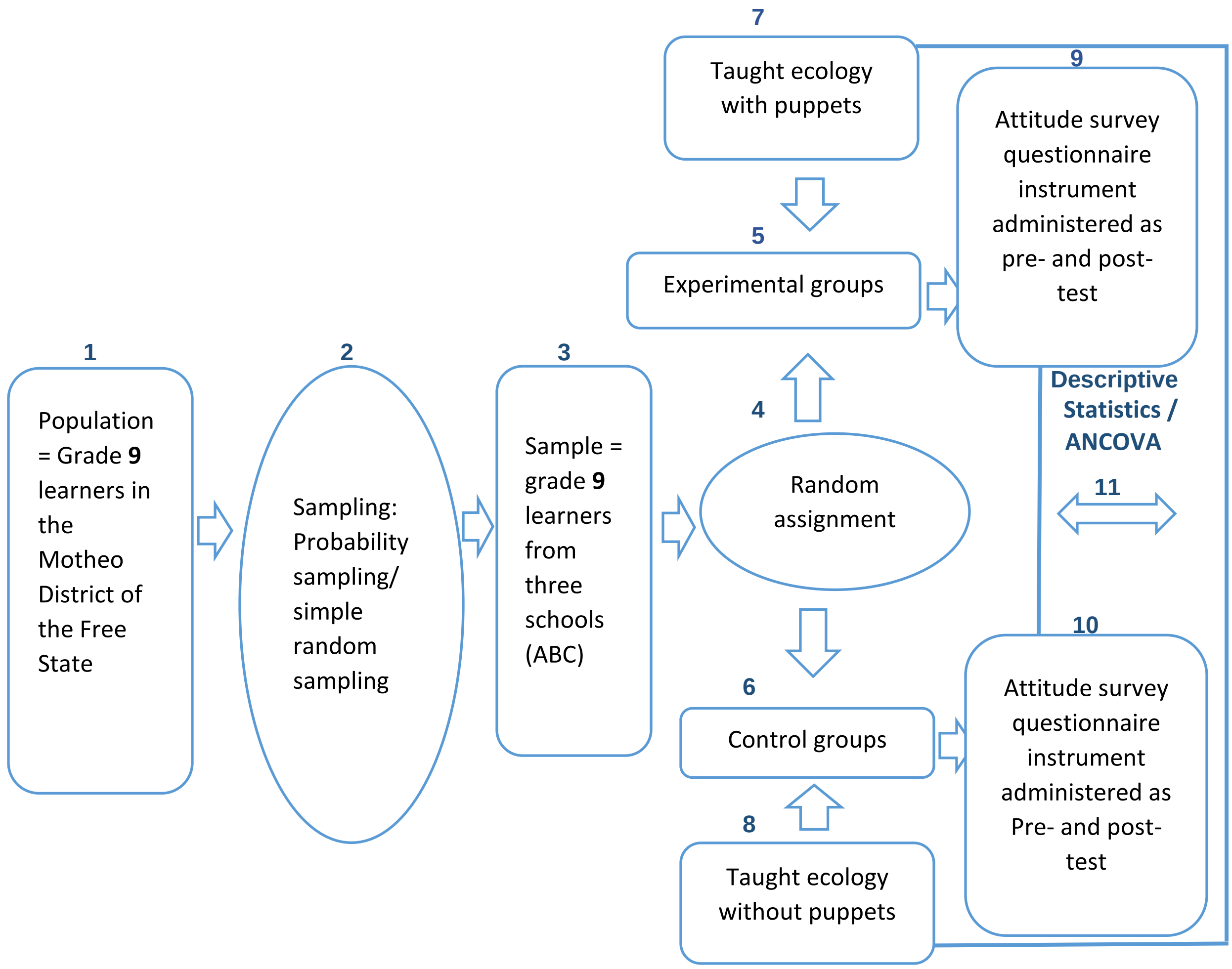

Figure 4.2 An overview of the steps taken in the collection and analysis of data (Alferes 2013:7)

4.5 The research population

In a quantitative research project, the population is the target group from whom the researcher wishes to generalise (Babbie 2010:199; Kraska 2010:2; Litt 2012:1053). According to Drew et al. (2014:4), the research population refers to all constituents of any clearly defined group of people or objects who are the focus of an investigation. They further state that the population may be quite large or small, depending on the units or restrictions that are applied to describe the set. Without a clearly defined set of characteristics, it is unclear to whom the results are generalisable.

In view of the stipulations of the above-mentioned scholars, the population of this study consisted of all Grade 9 learners in the Motheo District of the Free State province of South Africa [see figure 4.2 (1)]. Furthermore, the population was defined using four relevant parameters: (a) they were male and female learners, (b) they were in Grade 9, (c) they were between the ages of 14 and 16, and (d) they were studying in the three selected schools out of the 58 high schools in the Motheo District of the Free State. The use of these restrictions and defined characteristics was to clearly define the population as well as excluding subjects with unwanted characteristics (Drew et al. 2014:5). According to these restrictions and defined characteristics the researcher was not interested in any other groups of learners.

The reason for the choice of Grade 9 learners is that Grade 9 is the exit class in the general education and training phase (GET). Therefore, the attitudes of learners towards science at this level is crucial because it might play a role in determining their choice of science subjects in the further education and training phase (FET). This has been documented by previous researchers, who revealed that the positive attitudes of learners are important in determining their choice of school subjects, especially science (Hassan 2018:2045; Mujtaba et al. 2018:646; Hacieminoglu 2019:63; Oon et al. 2020:91). According to the school curriculum in South Africa, all subjects are compulsory at the general education and training phase (GET) level, while at the further education and training phase (FET) level, learners are required to choose subjects that will lead to their future careers.

Sampling and the sampling methods employed in the selection of the subjects will be discussed in the next section.

4.6 Sampling

Sampling is the systematic examination of a portion or sample of a larger group of potential participants or population by the researcher with the aim of using the results to make generalisations that apply to the broader group or population (Fritz & Morgan 2012:2). The extent to which the research findings can be generalised or applied to a larger group or population is an indication of the external validity of the research. The process of choosing a sample is an integral part of designing a good research project. In theory, a good sampling method will result in a sample that is free from bias and which is reliable (Fritz & Morgan 2012:2).

The steps the researcher followed in the sampling process as proposed by Fritz and Morgan (2012:2) include the identification of the population, which is referred to as the target population, because it includes all the participants of interest to the researcher. From this population the researcher employed a simple random sampling design to create the selected sample (see figure 4.2 (3)), which is the smaller group of individuals selected from the population. Finally, the researcher ends up with the actual sample, which is composed of the subjects who agreed to participate and whose data are used in the analysis.

The advantages of the researcher using a sample as opposed to the entire population include cost-effectiveness, speed, convenience and potential for improved quality and reliability. Studying the sample rather than the entire population results in less data that need to be collected. It also leads to a shorter time lag and better-quality data (Fritz & Morgan 2012:3).

4.6.1 Sampling methods

Sampling is a very important step in research. It refers to the systematic method the researcher employs in the selection of a sample from the population in order to estimate proportions and means in the population (Bergan 2018:2). In order to choose a sampling method, the researcher considered such factors as the research question, study methodology and the size of the population (Berndt 2020:224).

The researcher therefore employed the probability sampling method (see figure 4.2 (2)) to draw samples according to pre-specified criteria from the population (Chow 2012:2). It is important to know how these samples were drawn because the sample mean is used to estimate the population mean. Moreover, one important purpose of this type of sampling method is to draw inferences about the population. Making inferences is simple and easy with a sampling scheme (Chow 2012:3).

4.6.1.1 Probability sampling

According to Affleck (2012:2), probability sampling is an approach to selecting individuals from a population in such a way that the individuals are selected by a random process. The relative frequency with which they are included in the sample is deducible. The individuals selected by this process are referred to as the subjects. This ensures a degree of objectivity, and the integrity of the process rests on the conditions of the selection process rather than on the acuity of the researcher (Affleck 2012:2).

The reason for the choice of this sampling scheme is that each person in the population has an equal chance of being selected (Onwuegbuzie & Collins 2007:281; Dawes 2012:2; Mujis 2011:18). It is more representative than other types of sampling methods and avoids researcher bias in the selection of participants. This sampling scheme is probably the best-known method of selecting subjects in order to obtain a sample that is representative of the population (Drew et al. Hosp 2014:13). One disadvantage of the method is that a complete list is needed for all the persons in the population, which makes it difficult in larger populations (Chow 2012:3; Berndt 2020:225).

Probability sampling is underpinned by the philosophical belief of post-positivism (Carpenter 2018:2). It is based on the ontological assumption that there is a single objective reality everyone universally experiences. It also postulates that the information gained from conducting a study to observe a phenomenon experienced by one sample, can be generalised to the larger population. Furthermore, the sampling methods used in experimental research are not context-specific but can be replicated across different studies (Carpenter 2018:2).

This sampling method also has the advantage of allowing estimates of sampling error. This enables the researcher to estimate the accuracy and representativeness of the participants (Babbie 2010:198). It eliminates researcher bias in the selection process and ensures that potential threats to external validity is reduced (Dawes 2012:2; Mujis 2011:18). This also greatly reduces the possibility that a biased group is selected (Drew et al. 2014:13).

During the process of selecting the participating schools, the number generator software, Miracle Salad, developed by Sunny Walker at miraclesalad.com, was used. For the computer software to generate a list of three schools, all 58 schools in the Motheo District of the Free State were numbered from 1 to 58 (Persaud 2010:5). The assigned numbers, 1 to 58, were typed into this number generator software, from which three schools were then selected. The researcher telephonically contacted the principals of the three selected schools to confirm the participation of their learners. The schools responded positively and indicated their willingness to participate.

The researcher presented copies of the permission letter from the Free State Department of Education research unit (see appendix C) that authorised the study the principals, along with the ethical clearance letter from the University of the Free State (see appendix D). The permission letters from the researcher addressed to each principal of the participating schools (see appendix E) were also presented to them. The permission letters requested the approval of the principals for the researcher to access the school premises and the facilities needed for the study. This was done to satisfy the ethical provisions for research in education as highlighted in Herrera (2012:2), Alferes (2013:16) and Persaud (2010:3). The selection process ensured that a proper sampling procedure was followed (Tye-

Williams 2018:5). The selected schools were designated as schools A, B and C (see figure 4.1).

A random number table (Fritz & Morgan 2012:4) was used to select the learners in the participating schools. During the selection and assignment of the subjects into the various groups, a combined total of 180 participants were selected in the experimental and 175 in the control groups from all the participating schools. This comprised of the learners who were available to participate in the study. Most of the learners resided in the school hostels. This number was made up 119 learners in school A, 60 in the experimental group and 59 in the control group, 118 learners in school B, 58 learners in the control group and 60 in the experimental group, and 118 learners in school C, 58 learners in the control group and 60 in the experimental group. The total number of learners that participated in the study were less than the initial estimates. Some of the learners chose not to participate and the researcher respected their decisions in line with the ethical considerations in educational research, as stipulated in Herrera (2012:3) and Alferes (2013:17).

In order to effectively carry out the study, the researcher selected an adequate sample size of 180 learners in the experimental groups and 175 in the control groups that was representative of the population (Chadwick 2018:2) of Grade 9 learners in the Motheo District. This ensured better generalisability of the findings. During the selection process, the researcher assigned consecutive numbers to each participant listed in the population frame. Once this was accomplished, a random number table was used to select those who served as subjects, as well as their groups (Drew et al*.* 2014:13; Tye-Williams 2018:4).

The researcher began the selection by assigning each subject with a number from 1 to 355. Afterwards, an arbitrary starting point on the random number table was selected (Persaud 2010:2). The researcher then moved down the column searching for the first numbers on the table that had 1 to 355 as their first digits to select the 180 subjects in the experimental groups and 175 subjects in the control groups.

As the researcher systematically read down the column (Persaud 2010:3), a number encountered by the researcher that matched one of the assigned numbers in the population frame, designated an individual as a subject in that specific group (Drew et al*.* 2014:14). The numbers that were not part of the population frame list were ignored. The subjects selected were interpreted as being representative of the larger population, which enabled the researcher to arrive at a more generalised conclusion (Auspung & Hinz 2015:18).

The advantages of this sampling method, with a known probability of drawing each sample, was used to quantify the uncertainty of drawing conclusions about the population from a given sample (Tye-Williams 2018:4). It allowed for unbiased estimates of important population parameters (Bergan 2018:3), and also enabled the researcher to calculate and report the sampling error, which made it easier for the researcher to generalise on the results to the larger population of Grade 9 learners (Tye-Williams 2018:4).

The main limitation of this sampling method is that it is rather costly and time consuming (Tye-Williams 2018:4; Bergan 2018:3). The researcher was able to overcome this limitation by adhering to the suggestions of Kothari (2004:32), that research should be planned to be as efficient as possible by minimising the expenditure of effort, time and money. This was done by conducting the study in selected high schools in the Motheo District of the Free State. The researcher therefore did not travel long distances during the data collection process, and the cost of travelling from one school to another was greatly reduced.

Moreover, he solicited the help of the Grade 9 natural science teachers from the selected schools. They helped with control, assigning the selected subjects into their respective classrooms, and keeping order. This reduced the necessity of hiring and paying research assistants. The data collection exercise was spread over a period of six months and was carried out on designated Saturdays from April to September 2019. This enabled the researcher to adequately plan for each of the data collection trips.

4.6.2 The research sample

The research sample is the subset of the population. It is smaller than the population to which it is connected (Huck, Beavers & Esquivel 2012:2) and refers to the group from which data are collected (Kraska 2010:2). Research samples are used in research because the researcher does not have the resources e.g. time, money, or access to study the entire population of interest. After the identification and study of the sample, the researcher summarised the sample data and then used what he knew about it to make statistical inferences about the population (Huck et al. 2012:3).

In this regard the sample accurately represented the larger population. This ensured that accurate inferences could be drawn about the population (Drew et al. 2014:9). The emphasis therefore is on the representativeness of the sample, e.g. having the same characteristics as the population in approximately the same proportions, in order to facilitate generalisation (Chadwick 2018:3).

Many types of sampling are used in research studies. The various types differ from one another mainly in terms of the procedures utilised by the researcher to determine selection (Huck et al. 2012:3). The samples in this study were selected through probability methods, and the researcher applied certain restrictions, as stated earlier, to define their characteristics. This ensured homogeneity and an accurate representation of the population. Homogeneity ensured that the individual learners were similar in specific characteristics such as gender, age and grade. These similarities in specific characteristics were important to control for extraneous variables (Onwuegbuzie & Collins 2007:286 Chadwick 2018:2).

4.6.3 Selection of the participants

In research literature, the term participants are used to describe the individuals in a research project who are selected to participate in the research. They are the major units of analysis (Persaud 2010:2). In quantitative research the participants are called subjects because they are studied in order to gather data (Fritz &

Morgan 2012:2). Therefore, the participants in the study will be referred to as subjects.

As outlined in Persaud (2010:3), the subjects in a research study can be identified or selected using two methods, namely probability and non-probability sampling. The subjects in this study were selected using probability methods as was described in previous paragraphs. These methods involved selecting the subjects in accordance with probability theory (Babbie 2010:196). This sampling mechanism also ensured that no systematic bias occurred during the selection process (Persaud 2010:2).

4.6.4 Sample size

The choice of sample size in research is as important as the choice of sampling schemes, because it determines the extent to which the researcher can make statistical generalisations (Onwuegbuzie & Collins 2007:287). According to Drew et al. (2014:17), there is no sample size rule that is correct under all conditions, but given different circumstances, larger or smaller sample sizes may serve adequately. Auspung and Hinz (2015:36) also concur that an adequate participant sample size depends on the variability in the participants - the greater the variability, the more participants the researcher should use.

Some of the challenges faced by researchers when conducting quantitative research is utilising a sample size that is too small to detect any statistically significant differences (Onwuegbuzie & Collins 2007:297). Therefore, the sample size is critical in quantitative research. Larger samples ensure better representativeness and generalisability of the findings, as well as the proper use of statistical tools (Slevitch 2011:76). This implies that the size of the sample should be informed primarily by the research objectives, the research questions and the research design.

The sample size for this study consisted of 180 learners in the experimental groups and 175 learners in the control groups from all the selected schools. Although the total number of learners that participated were less than the initial proposed number, they nevertheless satisfied the minimum requirements to detect any statistically significant differences in the results (Drew et al. 2014:17).

4.7 Data collection

According to Kothari (2004:95), in order to select an appropriate method for data collection a researcher should consider the nature, scope and object of inquiry, as this constitutes the most important factors affecting the choice of a specific method. Moreover, the chosen method should suit the type of inquiry to be conducted as well as the nature of the research problem. Accordingly, the researcher utilised the Colorado Learning Attitude about Science Survey (CLASS) attitude questionnaire which was previously described (see 4.7.1.1) for data collection from the experimental and control groups (Mujis 2011:3; Drew et al. 2014:8; Scherbaum & Shockley 2019:6). The data collection method converted the phenomenon under investigation (the effectiveness of puppetry art as a teaching tool for learners' attitude change in natural sciences) into numerical data that was analysed statistically using descriptive statistics.

The use of the attitude survey questionnaire (see appendix A) limited bias, as the answers given were in the subjects' own words. The questionnaires were easy to complete, and the subjects had enough time to consider each answer carefully before answering (Kothari 2004:100). Moreover, research has shown that when subjects complete attitude surveys, they honestly report on their own beliefs although they do not know what the expert answers might be, as opposed to lying about them (Madsen et al. 2020:93). The main demerits of this data collection method lay in this researcher's inability to ascertain how well the beliefs reported by the subjects (Madsen et al. 2020:91) corresponded to the way they think about natural sciences.

4.7.1 Data collection instruments

According to James and Slater (2017:7), most doctoral programs strongly suggest the use of research instruments previously developed, tested and proven reliable for data collection. To ensure that the instruments are adequate to measure the intended constructs, validation tests to assess their reliability and validity are necessary (Leung & Shek 2018:4). The data collection instrument utilised in this study is the Colorado Learning Attitudes about Science Survey (CLASS) (see appendix A). This attitude survey instrument satisfied the above requirements (Madsen et al. 2020:90) as stipulated by the scholars. It was designed to measure learner beliefs and attitudes about science and learning science (Madsen et al. 2020:91).

It has been validated using interviews, reliability studies, and extensive statistical analyses of responses from over 5000 students (Adams et al. 2006:5). This attitude measurement instrument is frequently used in educational research to assess the different dispositions and traits of individual learners, including their attitudes towards science (Leung & Shek 2018:5).

The responses of the subjects were evaluated and statistically analysed to arrive at a valid conclusion (Miller 2011:5; Mujis 2011:6). According to Alferes (2013:7) and Madsen et al. (2020:90), pre- and post-test attitude surveys are important in measuring or assessing the shifts in learners' attitudes before and after the administration of an experimental treatment/intervention to the experimental group.

The data collection instrument, the Colorado Learning Attitudes about Science Survey, (CLASS), will be discussed in detail in the next paragraphs.

4.7.1.1 The Colorado Learning Attitudes about Science Survey (CLASS) and the rationale for the choice

Science education researchers had hoped that, as a result of learning science, learners will come to appreciate science as a coherent and logical method of understanding the world, since science uses reason and experimentation to figure out things about the real world. These prompted researchers to create survey instruments to assess learners' beliefs and attitudes about science (Madsen et al. 2020:90).

The CLASS attitude survey was chosen as the data collection instrument because it has gone through a development and testing process that ensured its validity and reliability. The expressions used in the survey made sense to the learners, and the surveyed contents was valuable, according to the experts (Madsen et al. 2020:91).

In addition to this, the instrument has undergone several rigorous validation and reliability studies involving several iterations to refine the survey statements (Adams et al. 2006:6). The validation process included face validity, which involved interviews and survey responses with students to confirm the meaning and clarity of statements, as well as construct validity, which involved the administration of the survey to several thousand students followed by extensive statistical analysis of their responses, including detailed factor analysis to create and verify the categories of statements and concurrent validity to ensure that it measures certain expected results (Adams et al*.* 2006:6).

The validation categories include categorisation philosophy, pragmatic design approach, reduced basis factor analysis and category names (Adams et al. 2006:7). The categorisation philosophy of the attitude survey incorporated both raw statistical approach and predeterminism. This ensured that the strengths of both approaches were utilised to obtain statistically robust categories. The pragmatic design approach ensured the process of choosing optimum categories. Reduced basis factor analysis ensured that the statistical validity of new categories was examined by carrying out factor analysis, and the category names were chosen after optimum categories had been determined (Adams et al. 2006:8).

4.7.1.2 The CLASS attitude survey as data collection instrument

The CLASS attitude survey (see appendix A) was used to measure how teaching ecology in natural sciences using puppetry art as a tool might impact learners' beliefs and attitudes towards natural sciences. This survey measures learners' self-reported beliefs about science, and how closely these beliefs align with experts' beliefs. It requires learners to rank statements using a five-point Likert scale from strongly agree=1, agree=2, neutral=3, disagree=4 to strongly disagree=5 (Adams et al. 2006:1).

The most common method used to score the CLASS attitude survey (see appendix A) was to determine for each subject, the percentage of responses for which the subjects' responses agree with the experts' view ("percent favourable") and then averaging these individual scores to determine the average percent favourable score (Adams et al. 2006:2). The survey was then scored overall for all eight categories of statements listed in table 4.3.

The overall score included eight categories, and excluded the "not scored" category, all of which have passed a validity and reliability test (Adams et al. 2006:2). The subjects were given a pre- and post-test to measure the "shift" or change in their beliefs (Madsen et al. 2020:90). The outcome of this was determined by looking at the changes in these beliefs and attitudes (Madsen et al. 2020:90) and analysing them using descriptive statistics.

The attitude measurement instrument is designed to measure learners' attitudes towards science and learning science. The instrument extended previous work done by existing surveys by probing learners' beliefs about science and learning science and differentiating between the beliefs of the experts and those of novices (Adams et al. 2006:1). The wording is suitable for learners in a wide variety of science classes, and it is designed to take little time to complete (Adams et al. 2006:2).

The pre- and post-test attitude measurement instrument included a set of 43 statements that described the attitudes of the learners towards learning natural sciences (see table 4.3). These statements were grouped into the following categories, which are aligned to the sub-questions of the main research question:

(a) real-world connection: can the application of puppetry art as a teaching tool to teach ecology influence learners' real-world connection category of their attitude towards natural sciences?

(b) personal interest: can the application of puppetry art as a teaching tool to teach ecology influence learners' personal interest category of their attitude towards the subject?

(c) sense-making/effort: can the application of puppetry art as a teaching tool to teach ecology influence learners' sense-making effort category of their attitude towards natural sciences?

(d) conceptual understanding and applied conceptual understanding: can the application of puppetry art as a teaching tool to teach ecology influence learners' conceptual and applied conceptual understanding categories of their attitudes towards natural sciences?

(e) problem-solving, general, problem-solving confidence and problem-solving sophistication: can the application of puppetry art as a teaching tool to teach ecology influence learners' general problem-solving confidence and sophistication categories of their attitudes towards natural sciences?

Table 4.3 below shows the categories as well as the statements comprising each category in the CLASS attitude survey (Adams et al. 2006:13).

Categories	Statements comprising categories
Real-world connection	28, 30, 35, 37,
Personal interest	3, 11, 14, 25, 28, 30
Sense-making/effort	11, 23, 24, 32, 36, 39, 42
Conceptual understanding	1, 5, 6, 13, 21, 32, 43
Applied conceptual understanding	1, 5, 6, 8, 21, 22, 40
Problem solving General	13, 15, 16, 25, 26, 34, 40, 42
Problem solving Confidence	15, 16, 34, 40
Problem solving Sophistication	5, 21, 22, 25, 34, 40
Not scored	4, 7, 9, 31, 33, 41

Table 4.3 Statement categories in the attitude survey (Adams et al. 2006:13).

4.7.1.3 Advantages of the CLASS attitude survey instrument

While some earlier attitude survey instruments focused primarily on aspects of epistemology or expectations, breadth, and a limited number of ideas in depth, the CLASS attitude survey instrument was shaped by several design principles which distinguishes it from the others. According to Adams et al. (2006:2), these design principles addressed a wider variety of issues educators consider to be important aspects of learning science, including clear and concise wording for each statement.

The written statements in the survey were meaningful even to learners who have never done science. The 'expert' and 'novice' responses to each statement were unambiguous, making it easier to score. It takes about ten minutes or less to complete the survey and it is easy to administer and score. The categorisation of questions into learner beliefs, was subjected to rigorous statistical analysis and only statistically robust categories were accepted, which characterised identifiable and useful aspects of learner thinking.

4.7.1.4 Possible limitations of the CLASS attitude survey instrument

The possible limitations of the CLASS attitude survey lie in its categorisation philosophy of pre-determinism. In pre-determinism, a set of categories are chosen based on the expert or teachers' perspective (Adams et al. 2006:5). These categories reflect the experts' categorisation and definition of useful beliefs for learning science, and their assessment of which statements will examine which one of those beliefs. This led to some categories not being valid when subjected to statistical tests because there was little co-relation between the responses, which may preclude learning anything new (Adams et al. 2006:5).

4.7.1.5 How the limitations in the CLASS attitude survey instrument were overcome

According to Adams et al. (2006:5-6), the limitations of the CLASS attitude survey could be overcome through the combination of the raw statistical approach and predeterminism to categorise questions. These overcame the limitations of using either of the approaches independently. In the raw statistical approach, there were no prior constraints, so the categories emerged purely from the data via exploratory factor analysis. This had the advantage of guaranteeing that there were statistically valid categories. Moreover, it provided insight into learner thinking and how best to characterise it.

The strength of predeterminism is that the categories were useful because they were of interest to the teachers. The advantages of both approaches were taken into consideration and effectively utilised to avoid their weaknesses. This led to obtaining statistically robust categories that best characterised learner thinking in the academic context in which the survey was used (Adams et al. 2006:5).

4.7.2 Data collection procedure

The cultural historical activity theory (CHAT) was applied during data collection to determine the effectiveness of the application of puppetry art as a teaching tool within the context of STEAM. Puppetry art was used as the mediating artefact or tool to teach Ecology to the experimental groups. The subject was the natural sciences teacher who used the tool as a means to determine possible attitude change. The rules were the parameters that guided how the learners were assessed using the CLASS attitude survey as a pre- and post-tests. The community was represented by the schools where data collection was done. Division of labour was depicted by the roles of the teacher and learners during data collection. The object was represented by the objective of the data collection activity which is attitude change of the learners towards natural science. The outcome was the achievement of the desired attitude change towards natural science.

The following procedures, as suggested by Persaud (2010:3), Mujis (2011:9) and Leung and Shek (2018:3), were followed during the process of data collection. Firstly, the classroom environment in the three selected schools were controlled. This was done by ensuring that the two groups (experimental and control) were kept in separate but similar classrooms, without any form of disturbance, distraction, or interference. The study was conducted outside of the normal school times, on Saturdays. During these times the learners were relaxed, and the researcher had complete control over the classroom environment (Mujis 2011:19; Leung & Shek 2018:3).

How the attitude survey study was conducted was similar in all the participating schools. The subjects in the experimental and control groups were treated the same, except for the use of puppetry art as a teaching intervention in the experimental group. This was done to avoid researcher bias (Mujis 2011:19; Leung & Shek 2018:4).

After the identification of the subjects in the experimental and control groups, they were greeted by the researcher, and the purpose of the study was explained to them, as well as how they were selected for the study. They were assured that their responses would remain anonymous/confidential as was earlier indicated in the informed consent and assent letters signed by their respective parents/guardians. They were also informed that they were not in any way obliged or coerced into participating (Persaud 2010:3; Mujis 2011:19). The researcher was responsible for the presentation of the lessons using puppetry art as a tool during the data collection process.

During the collection of data, both groups did the pre-test (see figure 4.1 and appendix A) attitude survey questionnaire prior to the experimental treatment of the experimental groups. The control groups did not receive any experimental treatment. Afterwards, a post-test (see figure 4.1 and appendix A) was administered to both groups using the same instrument (Mujis 2011:7; Leung & Shek 2018:6).

While completing the pre- and post-tests, the subjects were instructed to rank each statement that may or may not describe their beliefs/attitudes about learning natural sciences. This they did by ticking the choices that best expressed their feelings toward each statement. They indicated whether they “strongly agree”, “agree”, “neutral”, “disagree” or “strongly disagree” with any of the statements in a Likert scale style, ranging from 1 to 5, where 1 is strongly agree and 5 is strongly disagree. They were also instructed to leave vacant any statement they did not understand, and to select option 3 (neutral) if they understood a statement but did not have a strong opinion about it (Madsen et al. 2015:1; Madsen et al. 2020:91). The pre- and post- attitude survey responses from the subjects in the experimental and control groups were matched to ensure that the shifts in attitudes being calculated were actually the difference in the subjects’ thinking and not a difference in the number of learners who took the survey (Madsen et al. 2020:91).

The pre- and post-test attitude survey responses for both the experimental and control groups were compared and analysed statistically as was previously discussed, to determine if there were any statistically significant changes in attitudes which could be attributed to the effect of the experimental stimulus (the use of puppetry art as a teaching tool).

4.8 Data analysis

The researcher applied descriptive statistics in the analysis of the data. This enabled him to quantify and describe the basic characteristics of the data set. This was done using the computer programme SAS/STAT developed by the SAS institute in Cary, North Carolina. This is a widely used computer programme which greatly reduced some of the more tedious aspects of the data analysis (Drew et al. 2014:4).

It allowed the researcher to provide information on the measures of central tendency and dispersion on the pre- and post-tests for the experimental and control groups (Drew et al. 2014:3; May 2018:2). The measures of central tendency and dispersion provided the researcher with useful information for the data analysis (May 2018:9). In addition, it served as the starting point for data analysis allowing the researcher to describe, organise, and summarise data in a meaningful manner.

4.8.1 Statistical analysis

The pre- and the post-attitude survey responses of the 356 Grade 9 male and female subjects who participated in the experimental and control groups were compared to the answers given by experts on the same 43 statements/questions using the Colorado Learning Attitude about Science Survey (CLASS) Expert Response Key (see appendix B). This was done in order to reduce the large amounts of data into a more manageable form that allowed for the statistical analysis of the obtained data and drawing conclusions and insights about patterns observed in the data (Scherbaum & Shockley, 2019:3).

For each subject, the average number of questions (out of 43) that they answered in the same way as an expert were determined using the "percentage favourable score”. The “percentage unfavourable score” is the number of questions the subjects did not answer in the same way as an expert. “Neutrals” were scored as neither agree nor disagree with the expert. If the subjects left questions blank, the average percentage favourable score were calculated out of the number of questions that they answered (Adams et al. 2006:3). The subjects’ individual average percentage favourable scores were averaged to find the class average percentage favourable score.

This process was repeated to find the class average percentage unfavourable score, which is the number of questions the subjects did not answer in the same way as an expert would (Adams et al. 2006:2). Using this technique of descriptive statistics, the mean score was calculated for each individual question/statement in the attitude survey, where questions/statements were scored by study period (pre- and post-test) and by group (experimental and control). The mean score reflected the proportion of subjects who responded as an expert would. The mean score multiplied by 100 gave the percentage of the subjects who responded as an expert would or the “percent expert-like response” or “percent favourable response” (Madsen et al. 2020:90).

The n, mean, standard deviation, min, median, max, were also calculated for the above mean scores by study period (pre- and post-test) and by group (experimental and control). Furthermore, these descriptive statistics were also calculated by schools (A, B, C), study period (pre- and post-test), and by group (experimental and control) (Leung & Shek 2018:7). The analysis of covariance (ANCOVA) was later used to compare the outcomes between the experimental and control groups.

Analysis of covariance (ANCOVA) is a statistical control procedure that was used in the experimental design to remove the effect of one or more confounding variables. The software program SAS and the GLM procedure were used in the analysis of covariance (ANCOVA). It reduced unexplained outcome variance, thereby increasing the power of the treatment test effect, and reduced the width of its confidence interval (Van Breukelen 2012:2). It served to increase the sensitivity of the statistical test of the experimental factor in the statistical model (Sim 2018:2).

It was applied to reduce error variance, remove sources of bias, and obtain adjusted estimates of population means (Kirk 2014:2). One of the main advantages of the analysis of covariance (ANCOVA) is a reduction in error variance, and, hence, increased power and a reduction in bias as a result of differences among experimental units where those differences are not attributable to the manipulation of the independent variable (Kirk 2014:2). Regarding each questionnaire category, the experimental groups were compared to the control groups using the analysis of covariance (ANCOVA) with the mean score (post-test survey) of a category as dependent variable, and the following independent variables:

- School (three categories: A, B, C)
- Group (two categories: experimental and control)
- The corresponding mean score (pre-) as covariate

From these analyses of covariance (ANCOVA), the least square means post-intervention mean scores for each group (experimental and control) were calculated, as well as the "experimental – control" difference in mean scores, that is the 95% confidence interval for the mean difference, and the p-value for the test of the null hypothesis that the mean difference is 0 (that is, null hypothesis of no difference between experimental and control groups) (Kirk 2014:640; Sim 2018:4; Leung & Shek 2018:7).

Through the analysis of covariance ANCOVA, the dependent variable was adjusted to remove the effects of the uncontrolled sources of variation represented by the concomitant variable. This has the advantage of reduction in error variance, hence increasing the power to reject the null hypothesis, and also a reduction in bias caused by differences among the experimental units where those differences are not attributed to the manipulation of the independent variable (Kirk 2014:621).

4.9 Ethical considerations

Approval for the study was obtained from the research unit of the Free State Department of Education before the data collection process. Research ethics can be grouped into the following categories: (a) guidelines and oversight, (b) autonomy and informed consent, (c) standards and relativism, (d) conflict of interest, and (e) the art of ethical judgement (Herrera 2012:2; Alferes 2013:16; Persaud 2010:3). All these are aimed at a common theme for ethical consideration, which is that, the prerogatives of the study are secondary to the dignity and overall welfare of the subjects (Herrera 2012:3; Alferes 2013:17).

Research in education usually involves two groups of individuals, namely the researcher, who selects another group, the subjects, for study. Those in the latter group will usually know much less about the research and why they were selected. This can create a significant imbalance of power that may place the subjects in a subordinate position, leaving them vulnerable (Herrera 2012:3). This vulnerability can be addressed through ethical considerations (Persaud 2010:3).

Informed consent usually calls on researchers to provide a clear account of what might be in store for the subjects (Herrera 2012:4). This important issue was addressed in this study through the issuing of informed consent (see appendix F) and assent letters (see appendix G) to the parents/guardians of all the learners that participated. The letters asked for their consent for the participation of their children. In the letters the aim, purpose, information on the person conducting the study, the role of the learners as well as the duration of the study were clearly spelt out. The learners also received assent forms. They were advised that they had the right to withdraw their participation at any time, if they so wished, without any consequences whatsoever (Herrera 2012:4; Persaud 2010:3).

Ethics in research emphasises the need to protect the interests of the participants in the research process without compromising the standards of the research, as well as the protection of their privacy in quantitative data analysis and reporting

(Babbie 2010:446; Tangen 2014:678). In view of this, permission was sought from the Free State Department of Education (see appendix C) and the principals of the schools (see appendix E) where the research was conducted. The University of the Free State also authorised the research through the ethical clearance process (see appendix D). Although no ethical issues were anticipated during the research, action was taken to follow all the necessary steps involved in educational research.

4.10 Value of the research

Research in education is aimed at solving problems in the field. Educational research is an area of enquiry that involves taking a careful look at the educational situation and problems of human society and searching for solutions (Etudor-Eyo et al. 2011:917). In view of this, the research aims to explore the problem of negative attitudes of learners towards natural sciences and the possible use of puppetry art as a teaching tool to change their attitudes within the context of the STEAM educational approach.

This research therefore aims to contribute to the body of existing knowledge in curriculum studies on ways to improve learners' attitude towards the learning of natural sciences using puppetry art as a teaching tool. On an epistemological level, it will result in design principles that natural science teachers could use to implement puppetry art as a teaching tool in the natural sciences classroom. It will also make a methodological contribution by validating the use of puppetry art as a teaching tool for learner attitude change towards the learning of natural sciences.

4.11 Conclusion

In this chapter, the research design employed in data collection and analysis in order to answer the research questions were discussed. The objectives and the research methodology as well as the philosophical underpinnings of the quantitative approach of positivism and post-positivism were also discussed. The researcher justified his application of the quantitative experimental research approach. This was done through the review of relevant literature that supports the application of the methodology to gather and analyse data in order to answer the research questions and achieve the objectives.

A standardised data collection instrument, the Colorado Learning Attitude about Science Survey (CLASS) was used for data collection. The suitability of this instrument for data collection was justified through the extensive review of literature. The overview of the research design was presented in a flowchart (see figure 4.1) to summarise the different stages and the processes involved. The details of the population as well as the sampling methods were also discussed, detailing how the research sample size was arrived at.

CHAPTER FIVE

RESULTS

5.1 Introduction

In this chapter, the results of the quantitative data analysis for the study will be presented. Quantitative data analysis enabled the researcher to communicate the findings of the research (Scherbaum, & Shockley, 2019:2).

Descriptive statistics were used in the data analysis to summarise the data (Scherbaum & Shockley, 2019:4). This allowed the researcher to draw conclusions and insights about patterns in the data (Scherbaum & Shockley, 2019:3). Quantitative data analysis is not simply a set of techniques to be applied to data. It is the way the researcher systematically thought about the research questions, research methodology and the observed patterns in the data (Scherbaum & Shockley, 2019:2).

The epistemological perspectives of the study, namely positivism and post-positivism, postulate that there is an objective reality and suggests that the purpose of scientific investigation is to develop objective and generalisable facts and principles. This supports the quantification of information, measurements, and observations obtained in the course of the study, and are therefore compatible with the descriptive statistical analysis of the data obtained from the study (Scherbaum & Shockley, 2019:9).

The experimental control was used to obtain the unbiased estimates (Kirk, 2014:621) of the effectiveness of using puppetry art as a teaching tool to teach ecology to the experimental groups in the study. Analysis of covariance (ANCOVA) was applied to obtain the unbiased estimates of the treatment effect (i.e. using puppetry art as a teaching tool to teach ecology to the experimental groups) and at the same time to reduce error variance.

ANCOVA enables one to control for and remove the effect of covariates on the measured outcomes. The technique combines regression analysis with analysis of variance, and in this study involved measuring post-intervention values, fitting school and group (experimental vs control) as factors, and the corresponding pre-intervention value as covariates. School and the pre-intervention value represented the sources of variation that were controlled for in the analysis, as they were believed to potentially affect the independent variable, in addition to the dependent variable (Kirk 2014:621; Scherbaum & Shockley, 2019:4).

5.2 Scoring

Individual items in the attitude survey responses were scored as 1 if the subjects responded with “strongly agree” or “agree” for ‘A’ class statements/questions (those statements/questions with which experts “strongly agree” or “agree”), otherwise the score was zero (0). Similarly, individual statements/questions were scored as 1 if the subject responded with “strongly disagree” or “disagree” for ‘D’ class questions (those statements with which experts “strongly disagree” or “disagree”), otherwise the score was zero (0) (Madsen et al. 2020:92).

As discussed in Chapter 4, the attitude survey measured learners’ self-reported attitudes about natural sciences and how closely these beliefs align with experts’ beliefs. Experts in this context refer to individuals and educators who have expertise in various aspects of the teaching and learning of science, and the survey was designed to address a wide variety of issues which these experts consider as important aspects of learning science (Adams et al. 2006:3).

Expert beliefs, therefore, refer to a single interpretation of the response to each statement by the experts in the field of science. The "expert" responses to each of the statements were unambiguous, therefore the scoring of the responses was simple and obvious (Adams et al. 2006:3). The percentage of responses for which the subjects agreed with the experts' view (whether it was "agree", "strongly agree", "disagree" or "strongly disagree") regarding each statement was referred to as "percent favourable" score (Adams et al. 2006:4).

The descriptive statistics for the responses of the subjects to individual questions (see appendix H) in the attitude survey are discussed in the next section.

5.3 Descriptive statistics for individual questions in the attitude survey

For each individual item in the CLASS attitude survey, the mean score was calculated (where items were scored as described above) by study period (pre- and post-survey) and by group (experimental and control). The mean score reflected the proportion of subjects who responded as an expert would. The mean score multiplied by 100 is the percentage of subjects who responded as experts would, or the "percent expert-like response".

The descriptive statistics for the responses of the subjects to each statement in the pre- and post-attitude survey (see appendix H) were grouped into the following domains or categories, as shown in table 5.1 below. For each participant, the mean score for each category was calculated accordingly.

Category	Abbreviation	List of questions/statements whose mean score comprise the category
Personal interest	Pers_int	Q_3 Q_11 Q_14 Q_25 Q_28 Q_30
Real-world connection	RWC	Q_28 Q_30 Q_35 Q_37Q
Problem-solving general	PS_general	Q_13 Q_15 Q_16 Q_25 Q_26 Q_34 Q_40 Q_42
Problem-solving confidence	PS_confidence	Q_15 Q_16 Q_34 Q_40
Problem-solving sophistication	PS_sophist	Q_5 Q_21 Q_22 Q_25 Q_34 Q_40
Sense-making effort	SME	Q_11 Q_23 Q_24 Q_32 Q_36 Q_39 Q_42
Conceptual understanding	Conc_under	Q_1 Q_5 Q_ 6 Q_13 Q_ 21 Q_ 32 Q_43
Applied conceptual understanding	Appl_conc_under	Q_1 Q_5 Q_6 Q_8 Q_21 Q_22 Q_40

Table 5.1 The mean score of questions comprising each category/domain

Note that in each case the means of the available non-missing survey items were calculated. Descriptive statistics (total, mean, standard deviation, minimum, median, maximum) were also calculated for the above mean scores by study period (pre- and post-survey) and by group (experimental and control). Furthermore, these descriptive statistics were calculated by school, study period (pre- and post-survey) and by group (experimental and control).

The descriptive statistics for the percentage of "expert-like" responses of the subjects to all the categories of statements in the survey for all the schools are discussed in the next section.

5.4. Descriptive statistics for expert-like responses to questionnaire domains/categories

5.4.1 Personal interest (Pers_int) category (all schools)

Table 5.2 below indicates the percentage of expert–like responses of the subjects from both the experimental and control groups in all three participating schools (A, B, C) in the domain/category of personal interest (Pers_int) of the learners' attitudes towards natural sciences for the pre- and post-attitude survey. Table 5.2 indicates that 70.5% (0.705 × 100) of the subjects in the experimental groups responded as experts would, while 70.5% (0.705 × 100) of the subjects in the control groups also responded as experts would to the same category/domain of statements/questions in the pre-attitude survey.

In the post-attitude survey, 75.5% (0.755 × 100) of the subjects in the experimental groups responded as experts would, post-experimental intervention, to the same domain of statements/questions in the personal interest (Pers_int) category, while 71.2% (0.712 × 100) of the subjects in the control groups responded as experts would to the same category of questions/statements. Personal interest is an aspect of the learners' attitudes that influences their desire to understand a topic that persists over time. This desire increases their engagement in learning and knowledge acquisition (Sørebø & Hæhre 2012:350).

Domain		Period			
		Post-		Pre-	
		Group		Group	
		Control	Experimental	Control	Experimental
Pers_int	Total	175	180	175	179
	Mean	0.712	0.755	0.705	0.705
	Std.	0.23	0.23	0.23	0.24
	Min.	0	0.17	0	0
	Median	0.8	0.83	0.67	0.8
	Max.	1	1	1	1

Table 5.2 Descriptive statistics: expert-like responses for the domain of personal interest (Pers_int): all schools (pre- and post-survey)

5.4.2 Real world connection (RWC) category (all schools)

Table 5.3 below shows the percentage of the subjects in the experimental and control groups who responded as experts would to the domain/category of real-world connection (RWC) for schools A, B, C in the pre- and post-survey. The pre-attitude survey responses show that 57.4% (0.574 × 100) of the subjects in the experimental groups responded as experts would, while 59.2% (0.592 × 100) of the subjects in the control groups responded as experts would in the pre-survey as shown in table 5.3. The results from the post-attitude survey indicated that 61.1% (0.611 × 100) of the subjects in the experimental groups responded as experts would to the same category/domain of questions/statements of real-world connection post-experimental intervention, as compared to 59.0% (0.59 × 100) of the subjects in the control groups (see table 5.3) below.

Domain		Period			
		Post-		Pre-	
		Group		Group	
		Control	Experimental	Control	Experimental
RWC	Total	175	180	175	179
	Mean	0.59	0.611	0.592	0.574
	Std.	0.25	0.23	0.25	0.24
	Min.	0	0	0	0
	Median	0.75	0.75	0.75	0.5
	Max.	1	1	1	1

Table 5.3 Descriptive statistics: expert-like responses for the domain of real-world connection (RWC): all schools (pre- and post-survey)

5.4.3 Problem-solving general (PS_general) category (all schools)

The results of the category/domain of problem-solving general (PS_general), are indicated in table 5.4 below for schools (A, B, C). From table 5.4, a total of 55.0% (0.55 × 100) of the subjects in the experimental groups responded as experts would, as compared to 57.3% (0.573 × 100) of the subjects in the control groups in the pre-attitude survey. The post-survey, post-experimental intervention, shows that 59.0% (0.59 × 100) of the subjects in the experimental groups responded as experts would, as opposed to 57.6% (0.576 × 100) of the subjects in the control groups to the same domain/category of statements.

Domain		**Period**			
		Post-		Pre-	
		Groups		Groups	
		Control	Experimental	Control	Experimental
PS_general	Total	175	180	175	179
	Mean	0.576	0.59	0.573	0.55
	Std.	0.2	0.2	0.21	0.24
	Min.	0	0	0	0
	Median	0.63	0.63	0.63	0.57
	Max.	1	1	1	1

Table 5.4 Descriptive statistics: expert-like responses for the domain of problem-solving general (PS_general): all schools (pre- and post-survey)

5.4.4 Problem-solving confidence (PS_confidence) category (all schools)

In the category/domain of problem solving confidence (PS_confidence), the descriptive statistics for the results obtained in the attitude survey for all schools (A, B, C) indicated that 56.7% (0.576 × 100) of the subjects in the experimental groups and 58.7% (0.578 × 100) in the control groups responded as experts would in the pre-survey.

In the post-survey, 61.2% (0.612 × 100) of the subjects in the experimental groups and 58.7% (0.587 × 100) of the subjects in the control groups responded as experts would, post-experimental intervention with the experimental groups. This is shown in table 5.5 below.

Domain		Period			
		Post-		Pre-	
		Groups		Groups	
		Control	Experimental	Control	Experimental
PS_confidence	Total	175	180	175	179
	Mean	0.587	0.612	0.587	0.567
	Std.	0.27	0.26	0.27	0.29
	Min.	0	0	0	0
	Median	0.5	0.71	0.5	0.5
	Max.	1	1	1	1

Table 5.5 Descriptive statistics: expert-like responses for the domain of problem-solving confidence (PS_confidence): all schools (pre- and post-survey)

5.4.5 Problem-solving sophistication (PS_sophist) category (all schools)

The results from the descriptive statistics for the category/domain of problem-solving sophistication (PS_sophist) for all schools (A, B, C) are indicated in table 5.6 below. Table 5.6 shows that 38.8% (0.388 × 100) of the subjects in the experimental groups and 45.2% (0.452 × 100) of the subjects in the control groups responded like experts would to the pre-survey statements in the above category. In the post-survey, 40.6% (0.406 × 100) of the subjects in the experimental groups and 45.6% (0.456 × 100) of the subjects in the control groups responded as experts would to the same category of statements after the experimental intervention with the experimental groups. The above results are detailed in table 5.6 below.

Domain		Period			
		Post-		Pre-	
		Groups		Groups	
		Control	Experimental	Control	Experimental
PS_sophist	Total	175	180	175	180
	Mean	0.456	0.406	0.452	0.388
	Std.	0.21	0.2	0.21	0.22
	Min.	0	0	0	0
	Median	0.5	0.33	0.5	0.33
	Max.	0.83	0.83	0.83	1

Table 5.6 Descriptive statistics: expert-like responses for the domain of problem-solving sophistication (PS_sophist): all schools (pre- and post-survey)

5.4.6 Sense-making effort (SME) category (all schools)

Table 5.7 below shows the statistical analysis of the percentage of expert-like responses from the subjects in the experimental and control groups in the category/domain of sense-making effort (SME) for the participating schools (A, B, C) in the pre- and post-survey. From table 5.7, 62.0% (0.62 × 100) of the subjects in the experimental groups and 60.0% (0.60 × 100) of the subjects in the control groups responded to this category/domain as experts would in the pre-survey, while 63.8% (0.638 ×100) of the subjects in the experimental and 59.9% (0.599 × 100) of the subjects in the control groups responded as the experts would in the post-survey.

Domain		Period			
		Post-		Pre-	
		Group		Group	
		Control	Experimental	Control	Experimental
SME	Total	175	180	175	179
	Mean	0.599	0.638	0.6	0.62
	Std.	0.19	0.22	0.2	0.23
	Min.	0.14	0	0.14	0.14
	Median	0.57	0.71	0.57	0.57
	Max.	1	1	1	1

Table 5.7 Descriptive statistics: expert-like responses for the domain of sense making effort (SME): all schools (pre- and post-survey)

5.4.7 Conceptual understanding (Conc_under) category (all schools)

In the above specified category/domain of conceptual understanding for the pre- and post-survey for all schools (A, B, C), 33.0% (0.33 × 100) of the subjects in the experimental groups and 38.4% (0.384 × 100) in the control groups responded as experts would in the pre-survey, while 28.1% (0.281 × 100) of the subjects in the experimental groups and 43.4% (0.434 × 100) of the subjects in the control groups responded as experts would in the post-attitude survey, after the administration of the experimental stimulus. This is shown in table 5.8 below.

Domain		Period			
		Post-		Pre-	
		Groups		Groups	
		Control	Experimental	Control	Experimental
Conc_under	Total	175	180	175	180
	Mean	0.434	0.281	0.384	0.33
	Std.	0.21	0.22	0.2	0.22
	Min.	0	0	0	0
	Median	0.5	0.27	0.33	0.33
	Max.	1	0.83	0.83	1

Table 5.8 Descriptive statistics: expert-like responses for the domain of conceptual understanding (Conc_under): all schools (pre- and post-survey)

5.4.8 Applied conceptual understanding (Appl_Conc_under) category (all schools)

In the category/domain of applied conceptual understanding (Appl_Conc_under) for all schools (A, B, C) for the pre- and post-survey, table 5.9 shows that 24.7% (0.247 × 100) of the subjects in the experimental groups and 31.0% (0.31 × 100) of the subjects in the control groups responded as experts would in the pre-survey. In the post-survey, 22.0% (0.22 × 100) of the subjects in the experimental groups and 35.2% (0.352 × 100) of the subjects in the control groups responded as experts would, post-experimental intervention with the experimental groups.

Domain		Period			
		Post-		Pre-	
		Groups		Groups	
		Control	Experimental	Control	Experimental
Appl_Conc_under	Total	175	180	175	180
	Mean	0.352	0.22	0.31	0.247
	Std.	0.18	0.18	0.17	0.18
	Min.	0	0	0	0
	Median	0.33	0.29	0.29	0.29
	Max.	1	0.71	0.86	0.86

Table 5.9 Descriptive statistics: expert-like responses for the domain of applied conceptual understanding (Appl_Conc_under): all schools (pre- and post-survey)

5.5 Descriptive statistics for questionnaire domains/categories by individual schools

5.5.1 Personal interest (Pers_int)

When describing the responses from individual schools in the category/domain of Personal Interest (Pers_int) for the pre- and post-attitude survey, as is shown in table 5.10, school A had 66.9% (0.669 × 100) of the subjects in the experimental and 66.4% (0.664 × 100) of the subjects in the control groups respond as the experts would. In school B, 75.1% (0.751 × 100) of the subjects in the experimental group and 72.4% (0.724 × 100) of the subjects in the control group responded as experts would to this category/domain of questions. In school C, 69.3% (0.693 × 100) of the subjects in the experimental group and 72.6% (0.726 × 100) of the subjects in the control group responded as experts would in the pre-survey.

In the post-attitude survey responses to the same category/domain of questions, after the intervention in the experimental groups, 71.9% (0.719 × 100) of the subjects in the experimental group in school A and 67.4% (0.674 × 100) in the control group responded as experts would. In school B, 76.8% (0.768 × 100) of the subjects in the experimental group and 73.3% (0.733 × 100) of the subjects in the control group responded as experts would. In school C, 77.7% (0.777 × 100) of the subjects in the experimental group and 73.0% (0.73 × 100) of the subjects in the control group responded as experts would. Table 5.10 below indicates the result of the descriptive statistical analysis.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
Pers_int	School					
	A	Total	59	60	59	59
		Mean	0.674	0.719	0.664	0.669
		Std.	0.23	0.25	0.23	0.27
		Min.	0	0.17	0	0
		Median	0.67	0.83	0.67	0.67
		Max.	1	1	1	1
	B	Total	58	60	58	60
		Mean	0.733	0.768	0.724	0.751
		Std.	0.22	0.23	0.22	0.21
		Min.	0.17	0.17	0.17	0.17
		Median	0.83	0.83	0.83	0.83
		Max.	1	1	1	1
	C	Total	58	60	58	60
		Mean	0.73	0.777	0.726	0.693
		Std.	0.23	0.21	0.23	0.24
		Min.	0	0.33	0	0.17
		Median	0.83	0.83	0.83	0.67
		Max.	1	1	1	1

Table 5.10 Descriptive statistics for personal interest (Pers_int) by individual schools (pre- and post-survey)

5.5.2 Real world connection (RWC)

In the category/domain of real world connection (RWC), the analysis in table 5.11 shows that in the pre-survey, 55.1% (0.551 × 100) of the subjects in the experimental group and 56.1% (0.561 × 100) of the subjects in the control group in school A, 62.2% (0.622 × 100) of the subjects in the experimental group and 59.6% (0.596 × 100) of the subjects in the control group in school B, and 54.9% (0.549 × 100) of the subjects in the experimental group and 61.6% of the subjects in the control group in school C, responded as experts would. In the post-survey to the same category/domain of real world connection (RWC), 57.8% (0.578 × 100) of the subjects in the experimental group and 55.9% (0.559 × 100) of the subjects in the control group in school A, 61.7% (0.617 × 100) in the experimental group and 59.5% (0.595 × 100) in the control group in school B, and 63.8% (0.638 × 100) of the subjects in the experimental group and 61.6% (0.616 × 100) of the subjects in the control group in school C, responded as experts would.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
RWC	School					
	A	Total	59	60	59	59
		Mean	0.559	0.578	0.564	0.551
		Std.	0.23	0.22	0.23	0.24
		Min.	0	0	0	0
		Median	0.5	0.5	0.5	0.5
		Max.	1	1	1	1
	B	Total	58	60	58	60
		Mean	0.595	0.617	0.596	0.622
		Std.	0.24	0.25	0.24	0.25
		Min.	0	0	0	0
		Median	0.71	0.75	0.71	0.75
		Max.	1	1	1	1
	C	Total	58	60	58	60
		Mean	0.616	0.638	0.616	0.549
		Std.	0.27	0.22	0.27	0.23
		Min.	0	0	0	0
		Median	0.75	0.75	0.75	0.5
		Max.	1	1	1	1

Table 5.11 Descriptive statistics for real-world connection (RWC) by individual schools (pre- and post-survey)

5.5.3 Problem-solving general (PS_general)

In the category/domain of problem-solving general (PS_general) from the three participating schools (A, B, C), table 5.12 below indicates that, in the pre-survey, 52.7% (0.527 × 100) of the subjects in the experimental group and 55.0% (0.55 × 100) in the control group in school A, 54.5% (0.545 × 100) of the subjects in the experimental group and 56.6% (0.566 ×100) in the control group in school B, and 57.6% (0.576 × 100) of the subjects in the experimental group and 60.3% (0.603 × 100) in the control group in school C, all responded as experts would.

In the post-survey, in the same category/domain, 55.2% (0.552 × 100) of the subjects in the experimental group and 55.8% (0.558 × 100) in the control group in school A, 62.3% (0.623 × 100) of the subjects in the experimental group and 56.5% (0.565 × 100) in the control group in school B, and 59.5% (0.595 × 100) of the subjects in the experimental group and 60.3% (0.603 × 100) in the control group in school C all responded to the category/domain of questions as experts would, post-intervention.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
PS_general	School					
	A	Total	59	60	59	59
		Mean	0.558	0.552	0.55	0.527
		Std.	0.19	0.22	0.19	0.24
		Min.	0	0	0	0
		Median	0.63	0.6	0.57	0.5
		Max.	0.88	0.88	0.88	1
	B	Total	58	60	58	60
		Mean	0.565	0.623	0.566	0.545
		Std.	0.19	0.2	0.2	0.24
		Min.	0.13	0.13	0.13	0
		Median	0.63	0.63	0.63	0.57
		Max.	0.88	1	1	1
	C	Total	58	60	58	60
		Mean	0.603	0.595	0.603	0.576
		Std.	0.22	0.19	0.22	0.24
		Min.	0.13	0.13	0.13	0.13
		Median	0.63	0.63	0.63	0.63
		Max.	1	1	1	1

Table 5.12 Descriptive statistics for problem-solving general (PS_general) by individual schools (pre- and post-survey)

5.5.4 Problem-solving confidence (PS_confidence)

As shown in table 5.13 below in the category/domain of problem-solving confidence (PS_confidence), in the pre-survey, 55.4% (0.554 × 100) of the subjects in the experimental group and 56.1% (0.561 × 100) in the control group in school A, 56.8% (0.568 × 100) of the subjects in the experimental group and 55.5% (0.555 × 100) in the control group in school B, and 57.9% (0.579 × 100) of the subjects in the experimental group and 64.5% (0.645 × 100) in the control group in school C all responded as experts would to this category of questions.

In the post-survey, the responses to the same category/domain of questions from the experimental and control groups in school A was 57.4% (0.574 × 100) and 56.9% (0.569 × 100) respectively, in school B, 68.6% (0.686 × 100) of the subjects in the experimental group and 55.2% (0.552 × 100) in the control group, and in school C, 57.5% (0.575 × 100) of the subjects in the experimental group and 64.1% (0.641 × 100) in the control group, all responded as experts would post-intervention

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
PS_confidence	School					
	A	Total	59	60	59	59
		Mean	0.569	0.574	0.561	0.554
		Std.	0.27	0.27	0.28	0.29
		Min.	0	0	0	0
		Median	0.5	0.63	0.5	0.5
		Max.	1	1	1	1
	B	Total	58	60	58	60
		Mean	0.552	0.686	0.555	0.568
		Std.	0.26	0.25	0.27	0.31
		Min.	0	0	0	0
		Median	0.5	0.75	0.5	0.58
		Max.	1	1	1	1
	C	Total	58	60	58	60
		Mean	0.641	0.575	0.645	0.579
		Std.	0.26	0.24	0.26	0.29
		Min.	0	0	0	0
		Median	0.75	0.5	0.75	0.5
		Max.	1	1	1	1

Table 5.13 Descriptive statistics for problem-solving confidence (PS_confidence) by individual schools (pre- and post-survey)

5.5.5 Problem-solving sophistication (PS_sophist)

The percentage of expert-like responses in the category/domain of problem-solving sophistication in schools A, B, C, in the pre- and post-survey, as shown in table 5.14, indicated that in the pre-attitude survey, 36.5% (0.365 × 100) of subjects in the experimental group and 45.7% (0.457 × 100) in the control group in school A, 36.9% (0.369 × 100) of subjects in the experimental group and 42.3% (0.423 × 100) in the control group in school B, and 43.0% (0.43 × 100) of subjects in the experimental group and 47.5% (0.475 × 100) in the control group in school C, all responded as experts would to this category/domain of questions. In the post-survey, 39.7% (0.397 × 100) of subjects in the experimental group and 46.9% (0.469 × 100) in the control group in school A, 41.4% (0.414 × 100) of the subjects in the experimental group and 42.5% (0.425 × 100) in the control group in school B, and 40.9% (0.409 × 100) of the subjects in the experimental group and 47.5% (0.475 × 100) in the control group in school C, all responded as experts would to the PS_sophist domain of questions.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
PS_sophist	School					
	A	Total	59	60	59	60
		Mean	0.469	0.397	0.457	0.365
		Std.	0.21	0.21	0.21	0.17
		Min.	0	0	0	0
		Median	0.5	0.33	0.5	0.33
		Max.	0.83	0.83	0.83	0.67
	B	Total	58	60	58	60
		Mean	0.425	0.414	0.423	0.369
		Std.	0.2	0.21	0.2	0.24
		Min.	0	0	0	0
		Median	0.5	0.33	0.5	0.33
		Max.	0.83	0.83	0.83	1
	C	Total	58	60	58	60
		Mean	0.475	0.409	0.475	0.43
		Std.	0.2	0.2	0.21	0.23
		Min.	0	0	0	0
		Median	0.5	0.33	0.5	0.45
		Max.	0.83	0.83	0.83	1

Table 5.14 Descriptive statistics for problem-solving sophistication (PS_sophist) by individual schools (pre-and post-survey)

5.5.6 Sense-making effort (SME)

Table 5.15 below shows the percentage of expert-like responses of the subjects from the three schools (A, B, C) in the category/domain of sense-making effort (SME) in the pre- and post-survey. The subjects who responded as experts would in school A include 58.4% (0.584 × 100) in the experimental group and 53.7% (0.537 × 100) in the control group. In school B, 62.6% (0.626 × 100) of the subjects in the experimental group and 64.3% (0.643 × 100) in the control group, and in school C, 64.9% (0.649 × 100) of the subjects in the experimental group and 62.0% (0.62 × 100) in the control group all responded as experts would to this category in the pre-survey.

In the post-survey, 58.5% (0.585 × 100) of the subjects in the experimental group and 54.2% (0.542 × 100) in the control group in school A, 67.5% (0.675 × 100) in experimental group and 63.5% (0.635 × 100) in the control group in school B, as well as 65.3% (0.653 × 100) in the experimental group and 62.0% (0.62 × 100) in the control group in school C, all responded as experts would to this category/domain of questions.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
SME	School					
	A	Total	59	60	59	59
		Mean	0.542	0.585	0.537	0.584
		Std.	0.19	0.23	0.19	0.23
		Min.	0.14	0.14	0.14	0.14
		Median	0.57	0.57	0.57	0.57
		Max.	0.86	1	0.86	1
	B	Total	58	60	58	60
		Mean	0.635	0.675	0.643	0.626
		Std.	0.17	0.2	0.17	0.19
		Min.	0.17	0	0.17	0.14
		Median	0.57	0.71	0.57	0.57
		Max.	1	1	1	1
	C	Total	58	60	58	60
		Mean	0.62	0.653	0.622	0.649
		Std.	0.21	0.23	0.21	0.25
		Min.	0.14	0.25	0.14	0.14
		Median	0.62	0.71	0.67	0.71
		Max.	1	1	1	1

Table 5.15 Descriptive statistics for sense-making effort (SME) by individual schools (pre- and post-survey)

5.5.7 Conceptual understanding (Conc_under)

In the category/domain of conceptual understanding (Conc_under) in the pre-survey, the percentage of subjects that responded like an expert in school A was 27.9% (0.279 × 100) in the experimental group and 34.9% (0.349 × 100) in the control group. In school B, 30.4% (0.304 × 100) of the subjects in the experimental group and 38.3% (0.383 × 100) in the control group, as well as 40.6% (0.406 × 100) in the experimental group and 42.0% (0.420 × 100) in the control group in school C responded as experts would (see table 5.16).

In the post-survey, 25.1% (0.251 × 100) of the subjects in the experimental group and 39.9% (0.399 × 100) in the control group in school A, 25.6% (0.256 × 100) of the subjects in the experimental group and 40.2% (0.402 × 100) in the control group in school B, and 33.5% (0.335 × 100) of the subjects in the experimental group and 50.1% (0.501 × 100) in the control group in school C all responded as experts would to the same domain/category of questions.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
Conc_under	School					
	A	Total	59	60	59	60
		Mean	0.399	0.251	0.349	0.279
		Std.	0.21	0.22	0.2	0.21
		Min.	0	0	0	0
		Median	0.33	0.17	0.33	0.27
		Max.	0.83	0.83	0.67	1
	B	Total	58	60	58	60
		Mean	0.402	0.256	0.383	0.304
		Std.	0.23	0.21	0.23	0.22
		Min.	0	0	0	0
		Median	0.33	0.18	0.33	0.33
		Max.	0.83	0.67	0.83	0.83
	C	Total	58	60	58	60
		Mean	0.501	0.335	0.42	0.406
		Std.	0.19	0.23	0.18	0.23
		Min.	0.17	0	0	0
		Median	0.5	0.33	0.5	0.33
		Max.	1	0.83	0.83	1

Table 5.16 Descriptive statistics for conceptual understanding (Conc_under) by individual schools (pre- and post-survey)

5.5.8 Applied conceptual understanding (Appl_Conc_under)

Table 5.17 below shows the percentage of expert-like responses for schools A, B and C in the category/domain of applied conceptual understanding (Appl_Conc_under) in the pre- and post-survey. The statistical analysis indicates that 21.0% (0.21 × 100) of the subjects in the experimental group, and 30.8% (0.308 × 100) in the control group in school A, 23.3% (0.233 × 100) of the subjects in the experimental group and 30.3% (0.303 × 100) in the control group in school B, as well as 29.8% (0.298 × 100) in the experimental group and 31.8% in the control group in school C all responded as experts would to this category in the pre-survey. In the post-survey, 21.5% (0.215 × 100) of the subjects in the experimental group and 35.2% (0.352 × 100) in the control group in school A, 20.8% (0.208 × 100) of the subjects in the experimental group and 31.6% (0.316 × 100) in the control group in school B, and 23.8% (0.238 × 100) of the subjects in the experimental group and 38.7% (0.387 × 100) in the control group in school C all responded as experts would to this category/domain of questions/statements.

Descriptive statistics						
Domain			Period			
			Post-		Pre-	
			Group		Group	
			Control	Experimental	Control	Experimental
Appl_Conc_under	School					
	A	Total	59	60	59	60
		Mean	0.352	0.215	0.308	0.21
		Std.	0.18	0.19	0.17	0.15
		Min.	0	0	0	0
		Median	0.4	0.15	0.29	0.23
		Max.	0.71	0.71	0.57	0.57
	B	Total	58	60	58	60
		Mean	0.316	0.208	0.303	0.233
		Std.	0.17	0.19	0.16	0.17
		Min.	0	0	0	0
		Median	0.29	0.18	0.29	0.15
		Max.	0.71	0.57	0.57	0.71
	C	Total	58	60	58	60
		Mean	0.387	0.238	0.318	0.298
		Std.	0.18	0.18	0.18	0.2
		Min.	0	0	0	0
		Median	0.43	0.29	0.29	0.29
		Max.	1	0.71	0.86	0.86

Table 5.17 Descriptive statistics for applied conceptual understanding (Appl_Conc_under) by individual schools (pre- and post-survey)

5.6 Test of the null hypotheses on the first research question and derived sub-questions

These tests of the null hypotheses focused on the first research question and the derived sub-questions. In an attempt to answer the research questions, these hypotheses were tested to determine the significance of performance differences between the experimental and control groups in the pre- and post-tests. These hypotheses tested the influence of puppetry art as a teaching tool for learners' attitude change towards natural sciences, based on the following categories:

1. Learners' personal interest (Pers_int)
2. Conceptual understanding (Conc_under)
3. Applied conceptual understanding (Appl_Conc_under)
4. Sense-making effort (SME)
5. Problem-solving general (PS_general)
6. Problem-solving confidence (PS_confidence)
7. Problem-solving sophistication (PS_sophist)
8. Real-world connection (RWC)

The acronyms in brackets indicate the various codes that represent each construct used in the tests.

5.6.1 Comparing the influence of the application of puppetry art as a teaching tool on learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication, and real-world connection, and its influence on their change of attitude towards natural sciences

Research question 1

Can the application of puppetry art as a teaching tool to teach ecology within the context of the STEAM educational approach influence lead to a change in learners' attitudes towards natural sciences?

All sub-questions derived from the first research question

Can the application of puppetry art as a teaching tool influence learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication as well as real-world connection categories regarding their attitude towards natural sciences?

The null hypothesis for the sub-questions

The application of puppetry art as a teaching tool to teach ecology has no influence on learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication and real-world connection categories regarding their attitude towards natural sciences.

5.6.1.1 Research sub-question 1.1: Personal interest (Pers_int)

Can the application of puppetry art as a teaching tool to teach ecology influence learners' personal interest category regarding their attitude towards natural sciences?

Ho 1.1 *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' personal interest category regarding their attitude towards natural sciences.*

The ANCOVA results for testing this hypothesis (Ho 1.1) show a difference at 5% significance level between the post-test mean scores of the experimental and control groups [$F(1, 349) = 7.29$, $p = 0.0073$; table 5.18] in favour of the experimental group. According to these results, the experimental group performed significantly better than the control group (table 5.18). This indicates that the application of puppetry art as a teaching tool to teach ecology in the experimental groups had a significant influence on learners' personal interest in natural sciences, and an attitude change towards the subject. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on the personal interest category of learners' attitude towards natural sciences was rejected. This means that the use of puppetry art indeed had a positive effect on the personal interest category of learners' attitude towards natural sciences.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	11.29134082	2.82283521	139.99	<.0001
Error	349	7.03749785	0.02016475		
Corrected total	353	18.32883867			

R-Square	Coeff Var	Root MSE	Personal interest Mean
0.616042	19.37395	0.142003	0.732957

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.14694895	0.14694895	7.29	0.0073
School	2	0.05254215	0.02627107	1.3	0.2731
Pers_int_pre	1	10.87700774	10.87700774	539.41	<.0001

Table 5.18 ANCOVA results for the category of personal interest (Pers_int).

5.6.1.2 Research sub-question 1.2: Conceptual understanding (Conc_under) and applied conceptual understanding (Appl_Conc_under)

Can the application of puppetry art as a teaching tool to teach ecology influence learners' conceptual and applied conceptual understanding category regarding their attitude towards natural sciences?

5.6.1.2.1 Conceptual understanding (Conc_under)

Ho 1.2 (a) *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' conceptual understanding category regarding their attitude towards natural sciences.*

The above hypothesis [Ho 1.2 (a)] was tested and the ANCOVA results indicate that there is a significant difference between the post-test mean scores of the experimental and control groups. The ANCOVA results show a post-test mean score of [F (1,350) = 47,77 p <.0001) at 5% significance level in favour of the experimental group post-intervention [see table 5.19 (a)].

According to these results, the experimental group performed significantly better than the control group in their conceptual understanding of natural science concepts. They also had an attitude change towards natural sciences after puppetry art was applied as a teaching tool to teach ecology in the experimental group. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' conceptual understanding category regarding their attitude towards natural sciences was rejected. This means that the use of puppetry art as a teaching tool does indeed have a positive effect on learners' conceptual understanding category regarding their attitude towards natural sciences.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	9.73872372	2.43468093	96.65	<.0001
Error	350	8.81667065	0.02519049		
Corrected Total	354	18.55539437			

R-Square	Coeff Var	Root MSE	Conceptual understanding Mean
0.524846	44.54647	0.158715	0.356291

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	1.20338192	1.20338192	47.77	<.0001
School	2	0.10456649	0.05228325	2.08	0.127
Conc_under_pre	1	7.00468103	7.00468103	278.07	<.0001

Table 5.19 (a) ANCOVA results for the category of conceptual understanding (Conc_under).

5.6.1.2.2 Applied conceptual understanding (Appl_Conc_under)

Ho 1.2 (b) *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' applied conceptual understanding category regarding their attitude towards natural sciences.*

The ANCOVA results for testing this hypothesis [Ho 1.2 (b)] shows a difference at 5% significance level between the post-test mean scores of the experimental and control groups [$F(1,350)=36.45$, $p < .0001$; table 5.19 (b)] in favour of the experimental group. According to these results, the experimental group performed significantly better than the control group after the application of puppetry art as a teaching tool to teach ecology with the experimental group. This indicates that the application of puppetry art as a teaching tool had a significant influence on learners' applied conceptual understanding of natural science concepts and influenced an attitude change towards the subject. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' applied conceptual understanding category regarding their attitude towards natural sciences was rejected. This indicates that the use of puppetry art as a teaching tool did indeed have a positive influence on learners' applied conceptual understanding category regarding their attitude towards natural sciences.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	6.61131827	1.65282957	89.34	<.0001
Error	350	6.47534687	0.01850099		
Corrected Total	354	13.08666513			

R-Square	Coeff Var	Root MSE	Appl_Conc_under Mean
0.505195	47.68029	0.136018	0.285272

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.67429002	0.67429002	36.45	<.0001
School	2	0.05024762	0.02512381	1.36	0.2585
Appl_Conc_under_pre	1	4.9266661	4.9266661	266.29	<.0001

Table 5.19 (b) ANCOVA results for the category of applied conceptual understanding (Appl_Conc_under)

5.6.1.3 Research sub-question 1.3: Sense-making effort (SME)

Can the application of puppetry art as a teaching tool to teach ecology influence learners' sense-making effort category regarding their attitude towards natural sciences?

Ho 1.3 *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' sense-making effort category regarding their attitude towards natural sciences.*

The ANCOVA results for testing this hypothesis (Ho 1.3) show no significant difference between the post-test mean scores of the experimental and control groups (table 5.20) at 5% significance level [$F (1,349) = 2.6$, $p = 0.108$)]. According to these results, the experimental group had no significant performance difference from the control group in sense-making effort (SME) in natural science post-intervention after the application of puppetry art as a teaching tool to teach ecology with the experimental group, although the model overall was statistically significant at [$F = 95.76$, $p < .0001$ (see table 5.20)].

This result, therefore, shows that the competence of the experimental and control groups in sense-making effort (SME) overall was not significantly different after the intervention. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' sense-making effort category regarding their attitude towards natural science knowledge was accepted.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	8.05545576	2.01386394	95.76	<.0001
Error	349	7.33984936	0.02103109		
Corrected Total	353	15.39530511			

R-Square	Coeff Var	Root MSE	Sense-making Effort (SME) Mean
0.523241	23.44098	0.145021	0.618664

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.05459949	0.05459949	2.6	0.108
School	2	0.0957254	0.0478627	2.28	0.1042
SME_pre	1	7.36942251	7.36942251	350.41	<.0001

Table 5.20 ANCOVA results for the category of sense-making effort (SME)

5.6.1.4 Research sub-question 1.4: Problem-solving general (PS_general), problem-solving confidence (PS_confidence) and problem-solving sophistication (PS_sophist)

Can the application of puppetry art as a teaching tool to teach ecology influence learners' general problem-solving confidence and sophistication category regarding their attitude towards natural sciences?

5.6.1.4.1 Problem-solving general (PS_general)

Ho 1.4 (a) *The application of puppetry art as a teaching tool to teach ecology has no influence on the learners' problem-solving category regarding their attitudes towards natural science.*

The above hypothesis (Ho 1.4 a) was tested and the ANCOVA results indicate that there was no significant difference between the post-test mean scores of the experimental and control groups. The ANCOVA results show a post-test mean score of [F (1,349) = 2.86, p = 0.0914)] at 5% significance level post-intervention [table 5.21 (a)]. According to these results, the experimental group did not perform better than the control group in their general problem-solving abilities after puppetry art was applied as a teaching tool with the experimental group, although the model was significant at (F = 76.04, p <.0001) as indicated in table 5.21 (a).

The competence of the learners from the control group was not significantly different in their general problem-solving (PS_general) abilities from that of the learners in the experimental group after the intervention. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' problem-solving category regarding their attitude towards natural sciences was accepted [see table 5.21 (a) below].

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	6.70721673	1.67680418	76.04	<.0001
Error	349	7.69555825	0.02205031		
Corrected Total	353	14.40277498			

R-Square	Coeff Var	Root MSE	PS_general Mean
0.465689	25.51486	0.148493	0.581988

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.06317165	0.06317165	2.86	0.0914
School	2	0.05839705	0.02919852	1.32	0.2674
PS_general_pre	1	6.5387676	6.5387676	296.54	<.0001

Table 5.21 (a) ANCOVA results for problem-solving general (PS_general).

5.6.1.4.2 Problem-solving confidence (PS_confidence)

Ho 1.4 (b) *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' problem-solving confidence category regarding their attitude towards natural sciences.*

The results of testing the above hypothesis (Ho 1.4 b) showed no significant difference between the post-test mean scores of the experimental and control groups [F (1,349) = 3.51, p = 0.062] at 5% significance level [see table 5.21(b)]. From these ANCOVA results, the experimental group did not perform better than the control group post-intervention in problem solving confidence (PS_confidence) after puppetry art was applied as a teaching tool to teach ecology in the experimental group, although the model was significant at [(F = 92.09, p <.0001, (see table 5.21(b)]. This result shows that the competence of the learners in the control group was not significantly different from those of the experimental group after the intervention. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' problem-solving confidence category regarding their attitude towards natural sciences was accepted.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	12.36792715	3.09198179	92.09	<.0001
Error	349	11.71762291	0.03357485		
Corrected Total	353	24.08555006			

R-Square	Coeff Var	Root MSE	PS_confidence Mean
0.5135	30.58467	0.183234	0.599105

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.11772773	0.11772773	3.51	0.062
School	2	0.16992576	0.08496288	2.53	0.0811
PS_confidence_pre	1	12.15941889	12.15941889	362.16	<.0001

Table 5.21 (b) ANCOVA results for the category of problem-solving confidence (PS_confidence)

5.6.1.4.3 Problem-solving sophistication (PS_sophist)

Ho 1.4 (c) *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' problem-solving sophistication category regarding their attitudes towards natural sciences.*

Table 5.21(c) shows the ANCOVA results for testing the above hypothesis (Ho 1.4 c). The results indicate no significant difference between the post-test mean scores at 5% level between the experimental and control groups [F (1,350) = 0.22, p = 0.639]. According to these results, the experimental group did not perform significantly better than the control group post-intervention in problem-solving sophistication after puppetry art was applied as a teaching tool to teach ecology, although the model was statistically significant at [(F = 80.52, p <.0001; see table 5.21 (c)]. Since there were no significant differences between the two groups, it shows that the difference in competence of the learners in the control and experimental groups in problem-solving sophistication (PS_sophist) was not significant post-intervention. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' problem-solving sophistication category regarding their attitude towards natural sciences was accepted [see table 5.21 (c) below].

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7.15139964	1.78784991	80.52	<.0001
Error	350	7.77144386	0.02220413		
Corrected Total	354	14.92284351			

R-Square	Coeff Var	Root MSE	PS_sophist Mean
0.479225	34.57056	0.14901	0.431033

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.00486932	0.00486932	0.22	0.6399
School	2	0.02265832	0.01132916	0.51	0.6008
PS_sophist_pre	1	6.90167045	6.90167045	310.83	<.0001

Table 5.21 (c) ANCOVA results for problem-solving sophistication (PS_sophist)

5.6.1.5 Research sub-question 1.5: Real world connection (RWC)

Can the application of puppetry art as a teaching tool to teach ecology influence learners' real-world connection category regarding their attitude towards natural sciences?

Ho 1.5 *The application of puppetry art as a teaching tool to teach ecology has no influence on learners' real-world connection category regarding their attitude towards natural sciences.*

Table 5.22 below shows the ANCOVA results for the testing of the above hypothesis (Ho 1.5). The result indicates no significant difference at 5% level between the post-test mean scores of the experimental and control groups [F (1,349) = 3.03, p = 0.0828; table 5.22)] post-intervention, although the model was significant at (F = 82,38, p <.0001), as indicated in table 5.22. This result shows that the application of puppetry art as a teaching tool to teach ecology in the experimental group was not significantly different when compared to the control group in the learners' real-world connection (RWC) with the natural science content after the intervention. Therefore, the null hypothesis that the application of puppetry art as a teaching tool to teach ecology has no influence on learners' real-world connection (RWC) category regarding their attitude towards natural science content was accepted.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	9.70877388	2.42719347	82.38	<.0001
Error	349	10.28261422	0.02946308		
Corrected Total	353	19.9913881			

R-Square	Coeff Var	Root MSE	Real World Connection (RWC) Mean
0.485648	28.60578	0.171648	0.600047

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.08916011	0.08916011	3.03	0.0828
School	2	0.13563871	0.06781935	2.3	0.1016
Real World Connection_pre	1	9.45640316	9.45640316	320.96	<.0001

Table 5.22 ANCOVA results for the category of real-world connection (RWC).

Table 5.23 below shows the summary of the p-value for t-test of the null hypothesis that the mean difference is 0 (that is, null hypothesis of no difference between experimental and control groups), from the analysis of covariance (ANCOVA) for the various categories in the research questions, as was previously discussed in detail.

Category	Group Means[1]		Mean difference[1]: Experimental – Control		
	Experimental	Control	Point Estimate	95% Confidence Interval	P-value[2]
Personal Interest	0.753	0.712	0.041	0.011 to 0.070	0.0073
Real-World Connection	0.616	0.584	0.032	-0.004 to 0.068	0.0828
Problem-Solving General	0.595	0.568	0.027	-0.004 to 0.058	0.0914
Problem-Solving Confidence	0.617	0.580	0.036	-0.002 to 0.075	0.0620
Problem-Solving Sophistication	0.427	0.435	-0.007	-0.039 to 0.024	0.6399
Sense-making Effort	0.631	0.606	0.025	-0.005 to 0.055	0.1080
Conceptual Understanding	0.298	0.416	-0.117	-0.151 to -0.084	<.0001
Applied Conceptual Understanding	0.242	0.330	-0.089	-0.117 to -0.060	<.0001

Table 5.23 Comparison of experimental and control groups by group means and mean difference

The summary of the analysis of covariance (ANCOVA) results shown in table 5.23 above indicates that there were some significant differences in the p-values of the post-test between the experimental and control groups after the administration of the intervention (teaching ecology with the aid of puppetry art) to the experimental groups in some categories. These include the learners' personal interest (Pers_int) category regarding their attitude towards natural sciences [F (1,349) = 7.29, p = 0.0073], conceptual understanding (Conc_under) category regarding their attitude towards natural sciences [F (1,350) = 47.77, p < .0001], and the applied conceptual understanding (Appl_Conc_under) category regarding their attitude towards natural sciences [F (1,350) = 36.45, p < .0001].

In summary, the attitudes of the learners were similar towards natural sciences before the application of puppetry art as a teaching tool to teach ecology in the experimental groups. However, after the intervention, the learners from the experimental groups showed more positive attitudes in terms of their personal interests in learning natural sciences, as well as their conceptual and applied conceptual understanding of natural science concepts.

5.7 Conclusion

In conclusion, the results of the study showed that the application of puppetry art as a teaching tool in natural sciences was effective in improving the learners' personal interest in the subject, their conceptual understanding, as well as their applied conceptual understanding of natural science subject concepts. As was stated by the learners in the experimental groups, the use of puppetry art to teach them the balance in the ecosystem (loss of habitat, loss of species and climate change), conservation of the ecosystem (biodiversity and sustainability) and feeding relationships (food chains and food webs) in ecology, was enjoyable, interesting, and motivating. It helped them to understand those concepts in ecology clearly. This helped to improve some of the categories regarding their attitude towards the subject. The study results showed no significant influence on the learners' real-world connection, general problem-solving confidence and sophistication, as well as the sense-making effort categories regarding their attitude towards natural sciences.

The result seems to corroborate the findings of Najami et al. (2019:108), in which they found that using puppetry art to teach chemistry to tenth grade middle school learners had a positive effect on their learning of various chemistry concepts. The learners were found to have better scores than those taught without puppetry art. The learners also had a more positive attitude towards learning chemistry, which helped them to gain a better understanding of the concepts that could be difficult to comprehend when using traditional teaching methods.

It also seems to support the findings of Belohlawek et al. (2010:36-37), who found that using puppetry art to engage learners in a lesson developed their thinking about concepts in an inquiring and exploratory way. The findings of Simon et al. (2008:1245), in which they used puppetry art to teach science to Grade 9 learners, indicated that the puppets provided a stimulus for talk that involved the learners in reasoning and arguments. This provided a third context for classroom interaction, as it introduced a different style of interpersonal relationship which is productive for science learning. This also seem to be corroborated by the results of this study.

CHAPTER SIX

DISCUSSION OF RESULTS

6.1 Introduction

In this chapter, the findings of the study will be discussed. The study assessed the effectiveness of puppetry art as a teaching tool to change the attitudes of learners regarding natural sciences within the context of the STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach. The motivation for the study was to determine an alternative teaching approach, the use of the arts in science education, as a teaching tool for an attitude change of learners in natural sciences. According to the literature review, the declining attitudes of learners towards science, and how these can be addressed, have been a cause of concern for researchers over the years (cf. 1.1).

In the first section of this report, a discussion of the research findings on the effectiveness of puppetry art as a teaching tool for a change in attitude towards natural sciences will be made. Subsequently, the guidelines for the effective implementation of puppetry art as a teaching tool in natural sciences will be discussed.

6.2 The effectiveness of puppetry art as a teaching tool for attitude change within the context of the STEAM educational approach

The research questions aimed to assess the effectiveness of the application of puppetry art as a teaching tool to teach balance in the ecosystem (habitat loss, loss of species, and climate change), conservation of the ecosystem (biodiversity and sustainability), and feeding relationships (food chains and food webs) in ecology, within the context of the STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach, and how this might influence learners' attitude towards natural sciences. The analysis of covariance (ANCOVA) of the post-test mean scores of the experimental and control groups showed that the experimental group responded significantly better than the control group in some aspects, such as the personal interest, conceptual understanding and applied conceptual understanding categories. No significant difference was observed between the experimental and control groups regarding the learners' sense-making effort, general problem-solving confidence and sophistication, and real-world connection categories regarding their attitude towards natural sciences, when puppetry art was applied as a teaching tool to teach the topics in ecology mentioned earlier. The discussion of these results is presented in the next section.

6.2.1 The personal interest category regarding learners' attitudes

The result of the study indicates that the application of puppetry art as a teaching tool to teach the mentioned topics in ecology to the experimental group had a significant influence on the personal interest category of the learners' attitudes towards natural sciences [Experimental $F(1, 349) = 7.29$, $p = 0.0073$] (see table 5.18 in Chapter 5), when compared to the learners who were taught ecology using traditional teaching methods in the control group. This result indicates that the learners' desire to construct ecology knowledge that persists over time, and their engagement in learning and knowledge acquisition (personal interest), were significantly higher after the use of puppets to teach ecology. The question therefore arises as to what could have been the cause of the differences in their responses, given that both groups of learners had approximately the same competence in ecology prior to the intervention.

The differences in the responses of the two groups after the intervention can therefore be attributed to the teaching tool and how it was utilised in the ecology lesson to the experimental group. It can be argued that the application of puppetry art as a teaching tool to teach the mentioned topics in ecology influenced the outcomes regarding the personal interest category of learners' attitude towards the subject. Furthermore, numerous prior studies have confirmed, as reported in section 2.2.2, that the arts have the ability to help learners to draw on curiosity, observe accurately, think spatially, perceive aesthetically and work effectively with others (Sousa & Pilecki 2013:11).

The similarities between previous research outcomes and the study findings are the confirmation of the role of the arts in the effective teaching of science, aimed at changing the attitudes of learners towards the subject. Furthermore, the findings of the study on the personal interest category regarding learners' attitude towards natural sciences, are confirmed by prior research that the arts increase the scientific efficacy and creativity of learners, maximise their personal interests and motivation in science, and help to improve their scientific competitiveness (Kim & Chae 2016:1927). All of these contribute towards the development of a positive attitude towards natural sciences.

The positive effects of the use of puppetry art as a teaching tool on the personal interest category regarding learners' attitude, as was evidenced by the outcome of the study, consolidate the influence of the arts on the learners' ability to engage with the topics of balance in the ecosystem, conservation of the ecosystem, and feeding relationships (ecology) in natural sciences. This is highlighted by the outcomes of previous research on the importance of personal interest in the learning of science, which established that personal interests, and the learners' desire to understand a topic that persists over time, increase their engagement with learning and knowledge acquisition (Sørebø & Hæhre 2012:350), and may positively influence their attitude towards the subject. Previous studies have also discovered that personal interest plays a very important role in motivating learners to do their best, as it provides a much-needed boost (Afzal Humayon et al. 2018:134) for their persistence in carrying out a task, due to its cognitive and affective components.

This has also consolidated the outcome of the research by Hoft et al. (2018:186), who observed that personal interest is an outcome variable that is additionally decisive in the development of other outcome variables such as scientific literacy. Phan and Ngu (2018:56) inferred from their research that personal interest is likely to mobilise various psychological processes, such as an increase in effort expenditure, a high level of persistence, and/or engagement of deep cognitive strategies.

According to previous research outcomes, the application of the arts as a teaching tool in science has the advantage of enabling learners to see the overlap in practices between the arts and science (Tsurusaki et al. 2017:269). This minimises the barrier to the construction of science knowledge in a practical way (Fulton & Simpson-Steele 2016:10-11; Marmon 2019:105). This research outcome also corroborates the findings of the study on the positive influence of the personal interest category regarding learners' attitude when puppetry art was applied as a teaching tool to teach the mentioned ecology topics in natural sciences, as discussed in sections 2.1, 2.2.2 and 2.2.3. It can be argued, therefore, that the application of puppetry art as a tool in natural science teaching and learning influenced the personal interest category regarding learners' attitude towards the subject, which is critical to the learning of science.

This corroborates previous research outcomes, which revealed that there is a significant relationship between learners' achievement in science and their attitude (cf. 3.2.1). The implication of this is that learners' performance in natural sciences might have influenced their positive attitude towards it (Güney 2013:228; Wan & Lee 2017:509). This finding is corroborated by the result of the study as well as the outcomes of the research by Phan and Ngu (2018:57). In their study they found that a learner's positive assessment of his/her ability in a specific subject area influenced their academic achievement, which again influenced their attitude towards the subject.

Further to the importance of the integration of the arts to enhance science learning, Kim and Chae (2016:1927) discovered that the inclusion of the arts into the teaching of STEM (Science, Technology, Engineering and Mathematics) subjects increased learners' science efficacy and creativity, maximising their personal interest and motivation in science. This helped to improve their competitiveness in the construction of knowledge.

Subsequently, Kim and Kim (2016:1921) also established that the STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach encourages learners to take initiative in their learning, while De Beer et al. (2018:3) observed that the use of the arts in science learning is crucial. They found that it enables learners to develop creative thinking and scientific communication skills, as well as addressing their affective learning outcomes. These research outcomes seem to support the findings of the study and earlier discussions in section 2.2.2. It also supports the research outcome, which acknowledged the power of the arts as critical in engaging more diverse types of learners (Bush & Cook 2019:20) in the natural science classroom.

As was previously discussed in the literature review in section 2.2.2, the application of puppetry art as a teaching tool, exposed the learners in the experimental group to the common processes of science and arts. These include discovery, observation, experimentation, description, interpretation, analysis, evaluation, observing, wondering, visualising, exploring and communication (Fulton & Simpson-Steele 2016:2).

This helped to influence the personal interest category regarding their attitude, giving them an advantage over the learners in the control group. These differences can be linked to the arts' emphasis on combining knowledge and personal experiences, while science focuses primarily on the search for objective evidence to generate knowledge (Conner et al. 2017:2224).

Traditional teaching and learning methods seem to emphasise the importance of textbooks and curriculum materials as containing enough information for effective science learning. This assumption necessitated the adoption of these methods by teachers and learners without questioning them. Learners therefore tend to memorise lesson content as a means of sharing knowledge. The control group in the study seems to have adopted this approach, as was evidenced by the outcome of the study regarding the personal interest category regarding their attitude towards natural sciences.

Learners in the control group were taught ecology using the traditional teaching methods of textbooks and curriculum material, which may have limited their creative potential and excellence, as well as their personal interest in the subject, as creativity and imagination are required in natural sciences to visualise and understand abstract concepts (Turkka et al. 2017:1403). As discussed earlier in the literature review in section 2.1, traditional methods of teaching and learning and rigid, dogmatic adherence to rules of [curriculum materials, textbooks] and discipline are fundamentally incompatible with the true nature of science, because they place a focus on the study of science as a non-creative endeavour (Schmidt 2011:441). This might also have influenced the responses of the learners in the control group during the lesson presentation on Ecology and the post-test.

In summary, the findings of the study suggest that the application of puppetry art as a teaching tool in natural sciences significantly enhanced the personal interest category regarding the learners' attitude towards natural sciences. The efficacy of the arts in helping to improve learners' performance in science learning has been documented by previous research over the years. The findings of the study therefore are in agreement with the findings of Sousa and Pilecki (2013:29). They contend that the arts enable inspiration and novelty, as well as the development of cognitive and social growth. It also enhances creativity, reduces stress and makes science teaching and learning more enjoyable. It also supports the findings that the interdisciplinary nature of the STEAM educational approach has the potential to more deeply engage the learners (Cook et al. 2017:86), and improve their personal interest in the subject, because the arts enable multiple ways to explore science content (Turkka et al. 2017:1407). Therefore, the STEAM educational approach aims at the transformation of natural science teaching and learning to inform creativity, which may enhance the personal interest of the learners, which in turn may lower the barriers to practically construct knowledge (Fulton & Simpson-Steele 2016:10-11; Marmon 2019:105). This could also influence learners to change their attitude towards natural sciences, as was evidenced by the outcome of the study.

Finally, the learners who participated in the experimental groups also indicated that the ecology lesson (balance in the ecosystem, conservation of the ecosystem and feeding relationships) was insightful, interesting and enjoyable, which also supports the findings of previous research. On the other hand, the traditional method of teaching the same ecology topics by means of textbooks and curriculum materials seem not to have contributed much to influence the attitudes of the learners in the control group. These do not incorporate active learner participation and interactive tasks, and could account for the lack of significant changes in the personal interest of the learners in the control group towards natural sciences.

6.2.2 The conceptual understanding and applied conceptual understanding categories regarding learners' attitude

The ANCOVA results for the study that highlight the conceptual and applied conceptual understanding categories regarding learners' attitude towards natural sciences, reveal that the experimental group responded significantly better than the control group, with a post-test mean score of [Experimental $F(1,350)=47.77$, $p = <0.0001$] - see table 5.19(a) in Chapter 5. They also responded better in conceptual understanding [Experimental $F(1,350)=36.45$, $p = <0.0001$] - see table 5.19(b) in Chapter 5, and in the *applied* conceptual understanding categories regarding their attitude towards natural sciences when compared to the control group. The question therefore arises as to the cause of the difference in their responses, given that both groups of learners had approximately similar competence in conceptual understanding prior to the intervention.

It can therefore be argued that this outcome may similarly be attributed to the experimental groups being taught ecology using puppetry art as a teaching tool, while the control groups were taught the same topics using the traditional teaching method. The study outcome fits into the broader outcomes of previous research, as was earlier discussed in the literature review (cf. 2.2.3), in which scholars found that the STEAM educational approach enabled learners to deepen and situate their learning, and helped them to consolidate their understanding of theory and concepts in science (Lindquist et al. 2017:110). Some of these concepts include the role of habitat loss, loss of species and climate change in the disruption of the balance in an ecosystem, biodiversity and sustainability in the conservation of the ecosystem, as well as food chains and food webs in the feeding relationships amongst organisms in the ecosystem.

It therefore indicates that learners' understanding of the meaning of such ecological concepts, through thoughtful reflective mental activity as well as their ability to transfer these ideas into new situations and apply it to new contexts (conceptual and applied conceptual understanding of natural science concepts), was influenced by the application of puppetry art as a teaching tool, and is therefore important for science education (Hoft et al. 2018:188). The STEAM approach, therefore, enabled the learners to see themselves as designers and creators (Cook et al. 2017:86). This encouraged them to discover how to create new things, see familiar things in a new way, combine things in non-traditional ways, and think independently and unconventionally (Jamil et al. 2017:2).

It is expected that in natural sciences, where abstract concepts are part of the stipulated curriculum coverage, the application of puppetry art as a teaching tool will benefit learners' active construction of knowledge. This will influence the conceptual understanding category regarding their attitude towards the subject. The outcome of the study regarding the significant response of the experimental groups over the control groups in the conceptual and applied conceptual understanding categories regarding their attitudes towards natural sciences, clearly demonstrates the importance of the integration of the arts into science learning.

Conceptual understanding enabled the learners to grasp ideas about concepts (Aydin Ceran & Ates 2020:150) such as those mentioned in previous paragraphs. Applied conceptual understanding refers to the ability to transfer the acquired knowledge and ideas into new situations and apply it to new contexts (Macanas & Rogayan 2019:207).

In other words, conceptual understanding cannot be learned by rote, it must be learned through thoughtful, reflective mental activity facilitated by the application of a learner-centred teaching approach, such as STEAM. This will enhance learners' ability to take what they have learnt about these concepts in the classroom and apply it across domains (applied conceptual understanding). According to previous research outcomes, conceptual and applied conceptual understanding is important in science learning, because in the learning process the relationships and similarities between concepts in ecology, for instance, can be demonstrated in a transferable manner to facilitate learners' application of what they have learnt, in order to solve problems (Macanas & Rogayan 2019:207).

According to the outcomes of previous research, the STEAM approach utilises project-based learning as a vehicle for learning scientific concepts (Opperman 2016:1) to ensure active participation of the learners. This keeps them cognitively and meaningfully engaged with the learning content (Pino-Pasternak & Volet 2018:1523). The results of the study therefore suggest that the application of puppetry art as a teaching tool in the experimental group highlighted creativity, emotional touch and convergence between the arts and science disciplines (Park et al. 2016:1742). This influenced the conceptual and applied conceptual understanding categories regarding learners' attitude towards natural sciences.

This added the affective component to complex science concepts, making them more accessible and more engaging (Smith & Paré 2016:212; Bush & Cook 2019:20) to the learners. This reinforced a change in attitude towards natural sciences by the learners, which is crucial for knowledge construction. This is in consonance with the findings of Marmon (2019:104), that puppetry art specifically provides a platform for the presentation of natural science lessons that leads to the effective and meaningful construction and application of knowledge (cf. 2.3).

Previous research outcomes have also confirmed that a meaningful construction of knowledge occurs when learners are actively engaged with the content (Chi & Wylie 2014:219), cognitively involved, and participating in the learning process (Pino-Pasternak & Volet 2018:1523). This indicates that active participation by the learners in learning the content, can be achieved when lessons are delivered via a learner-centred approach. This will ensure a positive influence regarding the conceptual understanding category of learners' attitude, enabling them to perceive that they understand and have a functional grasp of the concepts being taught.

Puppetry art, therefore, is a teaching tool in natural science lessons that might lead to the effective and meaningful construction and application of knowledge (Marmon 2019:104). This can be inferred from the outcome of the study, which revealed that the experimental groups responded significantly better than the control groups in these categories regarding their attitude towards natural science concepts. In addition, this teaching tool also influenced an attitude change by the learners (Sasway & Kelly 2020:14).

The research outcomes have also indicated that memorising concepts will not increase the science process skills of learners. This will rather happen through the freedom to probe and explore the content through conceptual understanding of the concepts, comprehending why it is important to be knowledgeable in science, and the type of contexts in which it is useful, as well as applying it across domains (Macanas & Rogayan 2019:207). All of these will increase learners' science process skills. This clearly demonstrates why the experimental groups responded significantly better than the control groups.

The ecology lesson, with topics described previously, was delivered to the control group through the traditional teaching method of textbooks. It was inferred that this did not keep the learners actively and meaningfully engaged with the content, because it could only enable them to memorise the lesson content (cf. 2.1). Recent research outcomes indicate that developing conceptual understanding is a process involving an in-depth understanding that is realised by the structuring of the concepts (Aydin Ceran & Ates 2020:150). This in-depth understanding was achieved in the experimental group through the application of puppetry art as a teaching tool.

Further evidence from the literature review, as stated in section 3.2.1, suggests that there is a significant relationship between learners' achievement in science and their attitudes (Aslan 2017:2; Hacieminoglu 2019:63;78), because their behavioural action towards the subject correlates with their attitudes. This is the practical representation of their behaviour, which may result to either positive or negative actions or feelings towards science (Güney, 2013:227, Van Aalderen–Smeets & Van der Molen 2013:581; Oon et al. 2020:91). This implies that a positive influence in the conceptual understanding category regarding learners' attitudes, will enable them to display positive behaviour towards natural sciences, which will have an influence on their achievement in the subject.

Ajzen's theory of planned behaviour (TPB) postulates that the primary determinants of learners' behaviour towards natural sciences are their attitudes towards it (Yan & Sin 2015:207; Kelani & Gado 2018:83). This is again influenced by their underlying beliefs about the subject. This includes the beliefs about the likely consequences of studying the subject (cognitive beliefs), beliefs about the subjective affective/feelings (normative beliefs), and beliefs about the presence of contextual factors that may facilitate or impede the teaching and learning of natural sciences (behavioural control beliefs), as was earlier discussed in section 3.6.1. Based on the stipulations of Ajzen's theory of planned behaviour, I can, therefore, argue that the behaviour of the learners in the experimental groups towards natural sciences is most likely to be influenced by the conceptual understanding and applied conceptual understanding categories regarding their attitudes towards natural sciences.

This also reveals that there could be a significant correlation between the personal interest, conceptual understanding and applied conceptual understanding categories regarding learners' attitude towards natural sciences and the effective learning of the subject. This further consolidates the perspective from Ajzen's theory of planned behaviour perspective that learners' attitudes towards natural sciences are a strong predictor of their behavioural intentions. Their behavioural intentions are the antecedent of their actual behaviour (Van Aalderen–Smeets & Van der Molen 2013:578).

In summary, the STEAM educational approach, according to the literature, enabled the learners in the experimental groups to construct their own understanding of knowledge (Mi et al. 2020:551) of ecological concepts through discovery and the freedom to explore. This implies that the development of conceptual understanding is a process which requires an in-depth perception that is realised through the structuring of concepts (Aydin Ceran & Ates 2020:150).

On the other hand, I also want to also argue that the outcome of the response of the learners in the control groups could be attributed to their comparative negative attitude towards science due to them being taught using traditional and inefficient methods of teaching. According to the reviewed literature, learners' attitude towards science can be influenced by ineffective teaching methods, which makes science seem to be more difficult (Turner & Ireson 2010:119). From the outcomes of the study, and also from previous research outcomes, one can see that the teacher centred science teaching methodology, which relies mainly on textbooks and "chalk-and-talk", as well as rote learning, may lead to a negative attitude towards science by learners (Toma et al. 2019:508). This may account for the non-significant response of the control group in the conceptual understanding and applied conceptual understanding categories regarding their attitude towards natural sciences.

6.2.3 The sense-making effort category regarding learners' attitude

The outcome of the analysis of covariance (ANCOVA) of the post-test mean scores of the learners' sense-making effort (SME) category regarding their attitude towards natural sciences indicates no significant difference between the experimental and control groups, post-intervention [Experimental F (1,349) = 2.6, p = 0.108] (see table 5.20 in chapter 5). According to previous research outcomes, sense-making has been conceptualised as an approach that learners take to science learning (cf. 3.2.3.3). It is a dynamic process of building an explanation to resolve a gap or inconsistency in knowledge (Odden & Russ 2018:199) of science concepts.

The findings of the study in the sense-making effort category of the learners' attitudes post-intervention in the experimental groups did not demonstrate any difference or statistical difference between the experimental and control groups. This could be an indication that both groups have the same competence in the sense-making effort category regarding their attitudes towards natural sciences. It can also be an indication that in their cognitive processes, they may have had the same competence to fit new knowledge into existing knowledge frameworks which are built out of ideas that they have learnt from their experiences (Odden & Russ 2018:194).

The outcome of previous research on sense-making and its influence on a change in attitude by learners towards science has not been confirmed by the findings of the study. This may be subject to clarification by future research.

6.2.4 The general problem-solving category regarding learners' attitude

The outcome of the analysis of covariance (ANCOVA) of the post-test mean scores on the general problem-solving category regarding learners' attitude towards natural sciences confirms no significant difference between the experimental and control groups, post-intervention [Experimental F (1,349) = 2.86, p = 0.0914] - see table 5.21 (a) in Chapter 5. Previous research outcomes found general problem-solving to be a critical skill for attitude development in learners, because it enables them to cope with science learning (cf. 3.2.3.4). It also includes other skills such as reasoning and discretion (Palavan 2017:188).

Contrary to these research outcomes, the study result did not find any difference or significant difference between the responses of the learners' in the experimental and control groups in the general problem-solving category regarding their attitude towards natural sciences. This may be because puppetry art as a teaching tool did not have any influence, independently or collectively, and did not significantly influence the learners' general problem-solving category regarding their attitude towards natural sciences.

Therefore, the application of puppetry art cannot be said to have had any influence on any of the groups in the general problem-solving category regarding their attitude. The outcomes of the study also do not corroborate the outcomes of previous research and is also subject to verification by future research endeavours.

6.2.5 The problem-solving confidence category regarding learners' attitude

In the problem-solving confidence category regarding learners' attitude towards natural sciences, the outcome of the analysis of covariance (ANCOVA) of the post-test mean scores [Experimental $F(1,349) = 3.51$, $p = 0.062$] - see table 5.21(b) in Chapter 5- reveal no significant difference between the experimental and control groups, post-intervention. This gives an indication that both groups had the same competence before and after the intervention. According to previous research outcomes, problem-solving would allow the learners to have experiences that might enable them to develop self-confidence, to trust others and work co-operatively with them (Palavan 2017:189).

The results of the study, however, did not discover any difference or statistical difference between the experimental and control groups. It also seems to not agree with earlier findings that the application of drama in education indirectly improves the problem-solving skills of learners solely by increasing their self-confidence, because an increase in self-confidence levels results in an increase in problem-solving skills (Palavan 2017:190). It appears that the application of puppetry art as a teaching tool did not independently or collectively significantly influence the attainment of the problem-solving confidence category regarding learners' attitude. The outcome on this category of the learners' attitude towards natural sciences may also be subject to clarification by future research.

6.2.6 The problem-solving sophistication category regarding learners' attitude

In this category, the outcome of the analysis of covariance (ANCOVA) of the post-test mean score [Experimental $F(1,350) = 0.22$, $p = 0.639$] - see table 5.21 (c) in Chapter 5 - confirm no significant difference between the experimental and control groups, post-intervention. This gives an indication that both groups had the same competence before and after the intervention. According to previous research outcomes, as was discussed in the literature review, the application of drama as a teaching tool indirectly influences learners' problem-solving skills (cf. 3.2.3.3) but does not have a direct influence on their problem-solving sophistication.

This seems to be corroborated by the result of the study, which did not find any significant difference between the experimental and control groups in the problem-solving sophistication category regarding learners' attitude towards natural sciences. This seems to indicate that the application of puppetry art as a teaching tool did not independently or collectively significantly influence learners' problem-solving sophistication category regarding their attitude towards natural sciences. This seem to be consistent with the outcomes of previous research, as was earlier discussed.

6.2.7 The real–world connection category regarding learners' attitudes

The outcome of the analysis of covariance (ANCOVA) of the post-test mean scores on the real-world connection category regarding learners' attitude towards natural sciences, indicates that there was no significant difference between the experimental and control groups, post-intervention [Experimental $F (1,349) = 3.03$, $p = 0.0828$] - see table 5.22 in Chapter 5. According to previous research outcomes, a real-world connection helps to improve learners' motivation and interest in the subject, as well as their positive attitude towards it (Karakoç & Alacacı 2015:38). Furthermore, making real-world connections can contribute to improving learners' general performance and achievement in the subject (cf. 3.2.3.5). It can also provide an opportunity for improving the learners' problem-solving and analytical thinking skills, since it provides the learners with an environment and opportunities where they can develop multiple approaches to solving problems (Karakoç & Alacacı 2015:41).

Contrary to these research outcomes, the study results did not find any difference or statistical difference between the experimental and control groups in the real-world connection category regarding learners' attitude towards natural sciences when puppetry art was applied as a teaching tool to teach topics in ecology to the experimental groups. This seems to suggest that the application of the teaching tool to teach the experimental groups did not influence the competency of the learners in the real-world connection category regarding their attitude towards natural sciences. Secondly, the outcome of the study does not seem to corroborate earlier research findings on sense-making effort. This will also be subject to clarification by future research.

In summary, it appears that the application of puppetry art as a teaching tool to teach the mentioned topics in ecology to the experimental groups, influenced the personal interest, conceptual and applied conceptual understanding categories regarding the learners' attitude towards natural sciences. The same influence was not observed in the control groups, who were also taught the same topics and concepts in ecology using the traditional teaching method of textbooks.

6.3 Evaluation of the implications of puppetry art as a teaching tool for attitude change within the context of the STEAM educational approach

The study provides a new insight into the relationship between the application of puppetry art as a teaching tool, and a possible change in attitude of learners towards natural sciences. From the findings of the study, it is become evident that the application of the teaching tool positively influenced learners' attitude towards the subject by having a positive impact on the personal interest, conceptual and applied conceptual understanding categories regarding their attitude towards natural sciences. These results seem to be consistent with previous research outcomes on the importance of the arts in science education, as was previously discussed in the literature review (cf. 2.2.2). This tends to reinforce the influence of the arts in science education as a powerful and stimulating tool in the classroom.

Some research outcomes suggest that personal interest is very important in science education because it motivates learners and drives their persistence in carrying out a task (Sørebø & Hæhre 2012:350). This persistence to learn results in the acquisition of scientific literacy (Hoft et al. 2018:186), which positively influences their attitudes towards the subject. The outcome of the study tends to confirm that teaching with the aid of puppetry art positively influenced the personal interest, conceptual and applied conceptual understanding categories regarding learners' attitude towards natural sciences.

As was discussed in section 3.2.1, learners' attitude towards science is crucial in the teaching and learning of natural sciences. According to research outcomes, there is a significant relationship between learners' achievements in science and their attitude towards science (Aslan 2017:2; Hacieminoglu 2019:63,78). As a consequence, many scholars have attributed the development of a positive attitude by learners towards science to their personal interest in science, which is also linked to the instructional material and teaching approach utilised by the teacher (Ambusaidi & Al-Farei 2017:72; Hacieminoglu 2019:79; Sasway & Kelly 2020:2) to deliver lesson content. The application of puppetry art as a teaching tool, therefore, has been found by the study to be effective in influencing the personal interest category regarding learners' attitude towards natural sciences. This is consistent with the findings of Ambusaidi and Al-Farei (2017:72), Hacieminoglu (2019:79) and Sasway and Kelly (2020:2).

The implication of this is that the STEAM approach to science teaching could contribute significantly to addressing the decline in learners' attitude towards science, because attitudes consist of a variety of thoughts, values, feelings, and behaviours (cf. 3.2). It also encompasses concerns regarding the levels of difficulty, enjoyment or interest of learners towards natural sciences, which may inform their behaviour towards the subject (Ramsden 1999:127; Osborne et al. 2003:1045; Van Aalderen–Smeets et al. 2012:160; Van Aalderen-Smeets & Van der Molen 2013:581; Fasasi 2017:550; Chi et al. 2017:2172; Wan & Lee 2017:507; Hacieminoglu 2019:78; Aldahmash et al. 2019:5; Oon et al. 2020:92).

As discussed earlier in the literature, and derived from the outcomes of previous research, the STEAM educational approach utilises transdisciplinary approach, which incorporates the arts to enhance science education through exposing learners to a subjective view of the world, as a compliment to the objective view offered by science (Sousa & Pilecki 2013:10; Kim & Chae 2016:1928). This becomes important in the teaching and learning of natural sciences, because the incorporation of the arts as a tool in the delivery of the instructional content, draws the learners closer to science and influences their attitudes towards science (cf. 2.2.2).

This helps them to develop creativity as well as affective and aesthetic awareness (Najami et al. 2019:98) towards the subject. The study results seem to be consistent with the above research outcomes, because the application of puppetry art as a teaching tool seems to positively influence learners' attitude towards natural sciences by significantly influencing the conceptual and applied conceptual understanding categories regarding their attitude towards the subject.

Research outcomes also found that the arts approach to science teaching and learning, incorporates the application of theories, concepts and methods across disciplines, intent on holistically developing the learners (Lattuca 2001:83). This suggest that the approach can be applied to deliver natural science lesson content that positively influences the attitude of the learners towards the subject.

According to previous research outcomes, the ‘arts’ in the STEAM approach remain a medium for conceptualisation and ideation, or the exchange of ideas (Keane & Keane 2017:64). Previous studies have also found the arts to incorporate a collection of skills and thought processes that transcend all areas of human endeavour (Sousa & Pilecki 2013:17). This provides learners with opportunities to develop unique ways of knowing and interpreting the world (Keane & Keane 2017:63). It also fosters thoughtful reflections on the creative processes of the learners (Guyotte et al. 2015:30), which again enables their conceptual understanding of science concepts, as well as an attitude change, as the outcome of the study suggests.

The purpose of the inclusion of the arts in science teaching and learning in the STEAM approach, as discussed in section 2.2.3, is to deepen the learning experience of the learners rather than teaching the arts (Romagnoli 2017:25), since applied knowledge leads to deeper learning. This explains and corroborates the importance of the study findings on the influence of the application of puppetry art as a teaching tool on the applied conceptual understanding category regarding learners’ attitude towards natural sciences.

Further evidence from research, as discussed in section 2.3, described the application of puppetry art in the teaching and learning of science as “enabling the active participation of the learners in learning and keeping them cognitively and actively engaged with the content” (Pino-Pasternak & Volet 2018:1523). This active and cognitive engagement of the learners can be explained in terms of the influence of the STEAM approach on the conceptual and applied conceptual understanding categories regarding their attitude towards natural sciences. This can also be attributed to the teaching approach specifically providing a platform for the presentation of natural science lessons that can lead to the effective and meaningful construction and application of knowledge, as was reported by Marmon (2019:104).

The reviewed literature (cf. 2.3) indicated that in research carried out by Simon et al. (2008:1245), in which they used puppets to teach science to Grade 9 learners, they discovered that the puppets provided a stimulus for talk that involved the learners in reasoning, arguments, open questions, and justification of ideas. In all of these they responded positively to problems posed by the puppets. The researchers indicated that the use of puppets provided a third context for classroom interaction, which is productive for science learning, because it introduces a different style of interpersonal relationship between the learners the subject content and their interactions with the puppet.

The role of the puppets in the classroom, as was reported in the previous paragraphs, may have improved the self- efficacy of the learners, and made the learning of science more interesting (McGregor & Knoll 2015:339). This may also lead to an improved academic climate, improved attitudes towards science, as well as learners' confidence and self-worth, which makes science learning more engaging (Sasway & Kelly 2020:3-14). This research outcome is comparable to the study findings, because the use of puppets to teach the concept of balance in an ecosystem, conservation of the ecosystem and feeding relationships in ecology to the experimental groups, positively influenced the personal interest category regarding learners' attitude towards natural sciences.

6.4 Conclusion

In conclusion, this study provides insight into the educational benefits of applying puppetry art as a teaching tool. It reaffirms the findings from previous research that learners' attitude is important in the teaching and learning of natural sciences. It also found that the personal interest, conceptual, and applied conceptual understanding categories regarding learners' attitude towards natural sciences can be influenced by the application of puppetry art as a teaching tool. Learners' sense-making effort, general problem-solving confidence, and sophistication as well as the real-world connection categories regarding their attitudes towards natural sciences are not influenced by the application of the teaching tool. It also highlighted the significance of the arts in introducing creativity in the teaching and learning of natural sciences.

From the findings of the study, it can be argued that the learning of concepts in ecology, facilitated by the application of puppetry art as a tool in the experimental groups, were also significant, in that the puppets may have provided a stimulus that involved the learners in reasoning interaction. This is productive for science learning, as well as interpersonal relationships and creativity, which, according to researchers, are critical in effective science learning. One can deduce this from the influence it had on the personal interest, conceptual, and applied conceptual understanding categories regarding learners' attitude towards natural sciences.

The outcome of this study reaffirms the effectiveness of puppetry art in significantly enhancing learners' personal interest, conceptual, and applied conceptual understanding categories regarding their attitude towards natural sciences, which could improve learner performance and achievement in the subject. This implies that the learners will understand why natural science knowledge is important, and the type of context in which it is useful. Furthermore, the arts elicit creativity through thoughtful reflections on the learners' creative processes (Guyotte et al. Walther 2015:30) in natural sciences. This influences their higher levels of thought and ability to navigate difficult and stressful situations (Marmon 2019:106), because critical thinking facilitates the innovation required to transfer ideas into new situations and apply it to new contexts.

A change in attitude of the learners towards science therefore improves their outlook in the subject, and determines their inclination towards, and actions, in the subject (Fernández Cezar & Solano Pinto 2017:113; Hacieminoglu 2019:63). This study puts forward the implication that the personal interest, conceptual and applied conceptual categories regarding learners' attitude towards natural sciences benefit the learners' effective learning of natural sciences. The studied literature also indicated that a variety of appropriate teaching and learning tools in science will help to address the declining attitude of learners towards science (cf. 3.1). This seems to corroborate the findings of the study.

Moreover, the educational benefit of applying this teaching approach includes the learners' development of enhanced conceptual understanding, higher order thinking skills, interpersonal and personal interest, applied conceptual understanding and positive attitudes towards natural sciences. This is worth the time spent on the planning and implementation of this teaching approach. Adequate training is therefore necessary to prepare educators to effectively prepare appropriate content for the lesson, respond to learner questions, and address their misconceptions when implementing this teaching approach.

Finally, as was earlier stated, the application of puppetry art as a teaching tool in the experimental groups might have helped them to understand those concepts in ecology clearly. The learners in the control group wished they had been taught with the aid of the puppets, because according to them, they were not able to understand most of the concepts in the ecology lesson as explained by the teacher.

6.5 The limitations of the study

The challenges experienced during the course of this project, which may have impacted the outcomes, include the difficulty regarding the alignment of the timetables of the selected schools to accommodate the study during normal school hours, while at the same time avoiding the disruption of normal school activities. This, given the number of learners anticipated for the study, was a real challenge. There was also the challenge of teachers to assist to ensure a conducive environment for the study.

To overcome the first challenge, the study was conducted on Saturdays to avoid the disruption of normal school hours, and to ensure a conducive environment in which to conduct the study. Although this affected the number of learners who participated in the study, the number of participants nevertheless were sufficient to provide statistically significant results.

The second challenge was mitigated by the participation of natural science teachers from the respective selected schools, who offered their assistance to help with discipline and ensuring a conducive environment for the participation of the learners in the study. This prevented a chaotic environment and ensured that any introduction of extraneous variables, due to environmental factors that may have affected the outcome of the study, were eliminated.

Another concern was a situation where a variety of influences that might affect the outcomes of the study could occur, such as the influence of peers on each other. This limitation was also addressed through the assistance of the Grade 9 natural science teachers from the selected schools. They volunteered to assist and acted in concert as support personnel. They helped to maintain discipline and order throughout the duration of the study. They ensured that peer to peer discussion amongst the learners, as well as noise making was mitigated. This helped in the elimination of extraneous variables that may have been introduced, and which may have affected the outcomes of the study.
Due to the overall research design, the limitation of cost was also a challenge. This necessitated the localisation of the study to the Motheo District of the Free State province. It is beyond the scope of this study to address the question of unauthorised obstacles which may have affected the study outcomes, but care was taken to mitigate any unforeseen events that may have affected the study outcomes. Moreover, the learners that acted as the handlers of the puppets, and whose voices were heard, were not professional actors, which might have affected the efficiency of the puppets as a teaching tool. This should also be considered in future research endeavours.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter presents the summary and conclusions derived from the study, as well as the contribution of the study to the field of education. It also provides recommendations that will guide natural science teachers in the effective implementation of the teaching approach, as well as suggestions for future research on the application of puppets for effective science teaching and learning.

7.2 Summary of the study

The study set out to determine the effectiveness of puppetry art as a teaching tool for a change in attitude of learners in natural sciences. It was conducted at three different schools in the Motheo District of the Free State province. The participants were Grade 9 learners who were selected by random sampling. The study employed a quantitative research methodology and the experimental research design method. Data was obtained through pre-tests and post-tests using a standardised attitude survey, the Colorado Learning Attitudes about Science Survey (CLASS). Descriptive and inferential statistics were used in the analysis of the obtained data, while the analysis of covariance (ANCOVA) was employed to adjust the dependent variable to remove the effects of uncontrolled sources of variation represented by the concomitant variable in the test of the null hypothesis.

7.3 Summary of findings

The findings of the study were summarised according to the research questions and objectives, which were directly derived from the statement of the research problems as discussed in Chapter 1.

7.3.1 The main research question and hypothesis

Can the application of puppetry art as a teaching tool to teach ecology within the context of the STEAM educational approach influence learners' attitudes to change towards natural sciences?

The application of puppetry art as a teaching tool can influence learners' personal interest, conceptual and applied conceptual understanding, sense-making, general problem-solving confidence and sophistication as well as real-world connection categories regarding their attitude towards natural sciences.

7.3.1.1 Research sub-question one and objective one

Can the application of puppetry art as a teaching tool to teach ecology influence the personal interest category regarding learners' attitude towards natural sciences?

The objective related to this research sub-question was to determine if the application of puppetry art as a teaching tool would influence the learners' personal interest category regarding their attitude towards natural sciences.

In the personal interest category regarding the learners' attitude towards natural sciences, the data reveals that the obtained p-value of 0.0073 is less than the significance level of 0.05. Therefore, there is a significant difference between the experimental and control groups. The null hypothesis is thus rejected. This reveals that the experimental groups' response was significantly higher when compared to that of the control groups, when puppetry art was applied as a tool to teach balance in the ecosystem, conservation of the ecosystem, and feeding relationships (ecology) in natural sciences to the experimental groups. From the discussion of results in Chapter 6 (cf. 6.2.1), it is evident that the objective linked to research sub-question one was met.

7.3.1.2 Research sub-question two and objective two

Can the application of puppetry art as a teaching tool to teach ecology influence the conceptual and applied conceptual understanding categories regarding learners' attitude towards natural sciences?

The objective related to this research sub-question was to determine if the application of puppetry art as a teaching tool would influence learners' conceptual and applied conceptual understanding categories regarding their attitude towards the subject.

The data obtained for these categories reveal a p-value of $<.0001$ for both categories, which is less than the significance level of 0.05. This indicates that there is a significant difference between the experimental and control groups, and so the null hypothesis is rejected. It also indicates that the experimental groups responded significantly better than the control groups after being taught the topics and concepts in ecology mentioned earlier, using puppetry art as a tool. From the discussion in Chapter 6 (cf. 6.2.2), it was evident that the objective for this research sub-question was met.

7.3.1.3 Research sub-question three and objective three

Can the application of puppetry art as a teaching tool to teach ecology influence the sense-making effort category regarding learners' attitude towards natural sciences?

The objective related to this research sub-question was to determine if the application of puppetry art as a teaching tool would influence the learners' sense-making category regarding their attitude towards the subject.

The data for this category regarding learners' attitude towards natural sciences reveal a p-value of 0.108, which is greater than the significance level of 0.05. This shows that there is no statistical difference between the experimental and control groups. Therefore, the null hypothesis is accepted. This is also an indication that the two groups exhibited almost the same proficiency in the sense-making effort category regarding their attitude towards natural sciences before and after the researcher conducted the experiment.

7.3.1.4 Research sub-question four and objective four

Can the application of puppetry art as a teaching tool to teach ecology influence the general problem-solving confidence and sophistication categories regarding learners' attitude towards natural sciences?

The objective for this research sub-question was to determine if the application of puppetry art as a teaching tool will influence the learners' general problem-solving confidence and sophistication categories regarding their attitude towards natural sciences.

The data for these categories regarding learners' attitude towards natural sciences reveal a p-value of 0.0914 for the general problem-solving category, a p-value of 0.062 for the category of problem-solving confidence, and a p-value of 0.639 for the category of problem-solving sophistication. These p-values are greater than the significance level of 0.05, meaning that there is no significant difference between the experimental and control groups. Therefore, the null hypothesis is accepted. This reveals that the two groups exhibited almost the same proficiency and competence in the general problem-solving confidence and sophistication categories regarding their attitude towards natural sciences before and after the researcher conducted the experiment.

7.3.1.5 Research sub-question five and objective five

Can the application of puppetry art as a teaching tool to teach ecology influence the real-world connection category regarding learners' attitude towards natural sciences?

The objective for this research sub-question was to determine if the application of puppetry art as a teaching tool would influence the learners' real-world connection category regarding their attitude towards the subject.

The data for this category of the learners' attitudes towards natural science reveal a p-value of 0.0828. This p-value is greater than the significance level of 0.05, so there is no significant difference between the experimental and control groups. Therefore, the null hypothesis is accepted. This is an indication that the two groups exhibited almost the same proficiency and competence in the real-world connection category regarding their attitude towards natural sciences before and after the researcher conducted the experiment.

7.4 Conclusions

Based on the indicated findings, the following conclusions can be drawn:

- The learners in the experimental and control groups had almost similar level of basic knowledge in ecology before the intervention was applied to the experimental groups.
- The findings reveal that the learners in the experimental group, who were taught with the aid of puppets, had a better response compared to those in the control group, who were taught using the traditional teaching approach, in the personal interest, conceptual, and applied conceptual understanding categories regarding their attitude towards natural sciences.
- The application of puppetry art as a teaching tool in natural sciences proved to be more effective than the traditional teaching methods in influencing these categories of learners' attitude towards natural sciences.
- There was no statistically significant difference between the responses of the experimental and control groups in their sense-making effort, general problem solving, problem solving confidence, problem solving sophistication and the real-world connection categories regarding their attitude towards natural sciences.
- The learners in the experimental groups indicated that the application of puppetry art in the ecology lesson made the lesson more interesting and enjoyable.
- The specific feature of the lesson which contributed to the statistically significant response of the learners in the experimental group in the post-test, as attested by the learners themselves, was the use of puppets which made the ecology lesson hands-on, engaging and more interesting.
- The features of the traditional approach that may have contributed to the poor response of learners in the control groups, include a lack of active learner participation in the lesson such as discussions, debates and constructive feedback. This may have negatively influenced their responses as well as their attitude towards the subject.

7.5 Evaluation of the study methodology

Some aspects of the study methodology will be evaluated in terms of the problems encountered, their successes, and limitations. These include the participant population, sample of participants, data collection methods, the puppetry art intervention, and data analysis procedures.

7.5.1 The participants

The population consisted of Grade 9 learners from the Motheo District of the Free State province. The sample of learners who participated in the study included 180 in the experimental groups and 175 in the control groups, from three different schools. The sample was large, but a larger sample and the participation of more schools from other districts would have been better for generalisation purposes in terms of the findings. It would however not have been possible to have more schools and learners from other districts of the Free State to participating in the study, because of the financial and logistical constraints involved.

These include the training of the assistants/puppeteers, the acquisition of the materials needed to conduct the study, and the cost of transportation, accommodation, catering and other unforeseen expenditures. These financial and logistical constraints caused the localisation of the study to schools in the Motheo District. Nonetheless, during the generalisation of the study results, these constraints that restricted the data collection to only one district in the Free State, should be taken into consideration.

7.5.2 Data collection methods

The use of the Colorado Learning Attitudes about Science Survey (CLASS), a standardised attitude measurement instrument for data collection, proved effective in the collection of data for the study. As a result, useful insights into the effectiveness of puppetry art as a teaching tool for attitude change of learners in natural sciences were obtained. It is however possible that some of the participants may have skipped the pre- or post-test statements/questions, but this concern may not have had a profound impact on the results of the study. This is so because the pre- and post-test responses from the learners in the experimental and control groups were matched to ensure that the shifts in attitude being calculated were actually the difference in the learners' thinking, and not a difference in the number of learners who took the survey.

7.5.3 The STEAM / puppetry art intervention

One of the major challenges encountered during the fieldwork was how to keep the learners motivated and engaged with the study. However, in order to keep them motivated and engaged, the researcher instituted certain measures, including a thorough explanation of what the study was all about and why the study had to be conducted. The aim of the study was to investigate an alternative approach, the STEAM approach, to the teaching and learning of natural sciences, which would make it more attractive and more fun to learners, thereby influencing a change in their attitude towards the subject.

Secondly, the learners were also informed of the likely benefits the study would offer them, such as the ability to experience the application of puppets in the teaching and learning of natural sciences. Learners were also told that they were pioneers in such a ground-breaking project. Finally, refreshments were offered to those who participated in the study sessions as a means of keeping them motivated and engaged in the project. These measures kept the participants engaged and committed throughout the duration of the study. This also helped to minimise the number of learners who didn't participate in all the sessions.

7.5.4 Data analysis procedures

Descriptive and inferential statistics were used in the analysis of the data. In an attempt to limit the effects of extraneous variables that could influence the study outcome, the researcher applied the analysis of covariance (ANCOVA) as the main inferential statistics used for the data analysis in the study. Through the analysis of covariance (ANCOVA), the dependent variable was adjusted to remove the effects of the uncontrolled sources of variation represented by the concomitant variables. The ANCOVA had the advantage of reducing the error variance, hence increasing the power to reject the null hypothesis. It also allowed a reduction in bias caused by differences amongst the experimental units, where those differences were not attributed to the manipulation of the independent variable (Kirk 2014:2). This procedure was applied in the analysis of data to ensure the accuracy of the results (cf. 5.6.1).

In summary, the quantitative methodology employed in the study to collect and analyse data served its purpose. This was aimed at the systematic collection of empirical data on the effectiveness of puppetry art as a teaching tool for learners' attitude change in natural sciences within the context of the STEAM educational approach.

7.6 Possible contribution of the study to academic knowledge

This study is anticipated to make a number of considerable contributions to the existing body of knowledge in science education, especially towards contemporary research on the application of the arts in science education in general, and specifically the application of puppetry art as a teaching tool for learners' attitude change in natural sciences. Previous research outcomes reported that learners' attitudes towards science could be improved if teachers used appropriate instructional materials/tools and applied a variety of teaching approaches (Ambusaidi & Al-Farei 2017:72; Hacieminoglu 2019:79; Sasway & Kelly 2020:2) in their natural science lessons. The results from this study have shown that the application of this teaching tool in natural science education will influence the personal interest, conceptual and applied conceptual understanding categories regarding learners' attitude towards natural sciences.

This has the potential to enhance their content knowledge, creativity and conceptual understanding, and improve their attitudes towards natural sciences. This could also contribute in helping to minimise the declining attitudes of learners towards science (cf. 1.1; 3.2.1). This is so because puppetry art can be applied in the teaching of other topics in natural sciences and also in the teaching of other science subjects.

Secondly, the outcome of this study supports previous research findings (Simon et al. 2008:1231; De Beer 2015:1) that the application of the arts as a teaching tool in science education might help teachers to actively engage learners in the classroom. It might also assist them to make abstract concept in natural sciences more meaningful and easier for learners to internalise and construct conceptual knowledge, which will contribute to the improvement of learner attitudes towards science education (cf. 2.3).

Thirdly, previous research by scholars such as Mishra and Henriksen (2013:4) and Marmon (2019:105), found that instructional methods embedded in arts education have yielded more motivated and engaged science learners who were capable of increasing their learning. The application of puppetry art as a teaching tool, therefore, will specifically provide a platform for the presentation of natural science lessons that leads to effective and meaningful construction and application of knowledge through the influence on the learners' personal interest, and conceptual and applied conceptual understanding categories regarding their attitudes towards the subject. The result from this study, in concert with the above findings, have shown that the application of this teaching tool in natural sciences can indeed have some influence on learners' effective learning, as well as their ability to conceptualise and apply natural science knowledge that might lead to an attitude change towards the subject.

Fourthly, the outcomes of the study have highlighted the importance of the arts in science teaching to influence certain categories of learners' attitude towards science. This implies that the learners' cognitive and meaningful involvement in learning can be improved through the influence of puppets. This is because learners learn better through active participation and interaction, which might positively influence their attitudes, as the arts have multiple ways of expressing and exploring science content (Turkka et al. 2017:1408).

Finally, on an epistemological level, this study will result in design principles that will empower natural science teachers on the implementation of this teaching approach in their classrooms, as was discussed in the recommendations section. The study will also make a methodological contribution through the validation of the effectiveness of puppetry art as a teaching tool in changing learners' personal interest, conceptual understanding and applied conceptual understanding categories regarding their attitude towards natural sciences within the context of the STEAM educational approach.

7.7 Recommendations

Based on these findings, the following recommendations on the application of this teaching tool in the classroom are presented below:

1. To ensure the practical implementation of puppetry art as a teaching tool in classrooms, natural science teachers need to be trained through workshops organised by the Free State Department of Basic Education (FSDoE) on time management, learner-centred approach, development of a puppet script, as well as how to deliver a lesson for each topic where puppetry art will be applied. This will be of utmost importance towards the implementation of the STEAM educational approach. Most schools' timetables allocate a maximum of forty minutes per period in the senior phase, which might not

be enough for the implementation of a learner-centred lesson using puppets, because the time needed to implement the lessons could be longer.

2. Effective teaching and learning can be demanding and sometimes exhausting, making it impossible for adequate lesson preparation and implementation. In view of this, extensive training of educators through virtual webinar sessions is highly recommended to enable them to participate in the training from the comfort of their homes. This will serve as a motivation for them to fully participate in all the training sessions where they will learn all the necessary skills and practices needed to effectively implement the puppetry art STEAM approach in their respective classrooms.

3. A possible concern in the implementation of this teaching approach, which can be easily overcome, is the cost of procuring the puppets and how the approach might be implemented in large classrooms, which is typical of township schools. This might not interfere with the implementation, given that puppets can be made from recyclable materials that are readily available and are cost effective. Furthermore, large class implementation can be managed in small groups, as the application of puppetry art requires learners to work in small groups, while the teacher facilitates the lesson through puppets. This will lessen the burden of managing large classes and reduce the need for the procurement of more puppets. This makes the teaching approach implementable with minimal cost to schools, and can also help teachers to learn and become skilled in the use of puppets as teaching tools instead of relying on traditional instruction methods of teaching natural sciences.

4. The implementation of this teaching tool as a learner-centred approach in the teaching of natural sciences, should be encouraged by the Department of Basic Education (FSDoE), and embraced by the administrators of schools

and natural science teachers in an effort to continually improve the teaching and learning of the subject, as well as positively influencing declining learner attitude towards science. This approach should be seen a means of improvement in the teaching and learning of not only natural sciences, but other science subjects as well. Therefore, efforts should be made to embrace this approach by all stakeholders in education.

7.8 Suggestions for further study

The findings of this study present the need for further research opportunities in the following:

- It has been proven by the outcome of this study that the application of puppetry art as a teaching tool can indeed influence some aspects of learners' attitude towards natural sciences. Therefore, further research is needed in this field, specifically to ascertain whether this teaching tool can be applied to teach other science subjects in the further education and training phase (FET) to influence the attitudes of learners towards science.
- Research that will focus on ways to improve the implementation of the application of this teaching tool for improved learner performance in science.
- Further research should also be undertaken to investigate the potential of this teaching tool in motivating and influencing young learners to pursue science-related careers. It must be conducted to establish the long-term motivational effect of this teaching tool within the STEAM approach. Furthermore, it is recommended that further research should establish how best natural science teachers can be empowered through the provision of the necessary skills needed for the effective implementation of this teaching approach in their various classrooms.

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Appendix A

Data collection instrument

PRE AND POST ATTITUDE SURVEY

Names_____________________________________ **Grade**____

Introduction

Below are several statements that may or may not describe your attitudes about learning Natural sciences. You are requested to rate each statement by ticking the choices below that best expresses your feeling towards the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

SURVEY

	1 Strongly agree	**2 Agree**	**3 Neutral**	**4 Disagree**	**5 Strongly disagree**
1. A significant problem in learning natural science is being able to memorize all the information I need to know					
2. When I am solving a natural science problem, I try to decide what would be a reasonable value for the answer					
3. I think about the natural science I experience in everyday life					
4. It is useful for me to do lots and lots of problems when learning natural science					
5. After I study a topic in natural science and I feel that I understand it, I have difficulty solving problems on the same topic					
6. Knowledge in natural sciences consists of many disconnected topics					
7. As scientists learn more, most of the ideas we use today are likely to be proven wrong					
8. When I solve any natural science problem, I locate an equation that					

	1 Strongly agree	2 Agree	3 Neutral	4 Disagree	5 Strongly disagree
uses the variables given in the problems and plug in the values					
9. I find that reading the text in detail is a good way for me to learn natural science					
10. There is usually only one correct approach to solving a problem in natural science					
11. I am not satisfied until I understand why something works the way it does					
12. I cannot learn natural sciences if the teacher does not explain things well in class					

	1 Strongly agree	2 Agree	3 Neutral	4 Disagre e	5 Strongly disagree
13. I do not expect natural sciences equations to help my understanding of the ideas; they are just for doing calculations					
14. I study natural sciences to learn knowledge that will be useful in my life outside of school					
15. If I get stuck on a natural science problem initially, I usually try to figure out a different way that works					
16. Nearly everyone is capable of understanding natural science if they work at it					
17. Understanding natural sciences basically means being able to recall something you've read or been shown					
18. There could be two different correct values to a natural science problem if I use two different approaches					
19. To understand natural sciences, I discuss it with friends and other students					
20. I do not spend more than five minutes stuck on a natural sciences problem before giving up or seeking help from someone else					
21. Ecology is my best topic in Natural Science					
22. If I want to apply a method used for solving one natural science problem					

to another problem, the problems must involve very similar situations					
23. In doing a natural science problem, if my calculations give a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem					
24. In natural sciences, it's important for me to make sense out of formula before I can use them correctly					
25. I enjoy solving natural sciences problems					
26. In natural sciences formula express meaningful relationships among measurable quantities					
27. It is important for the government to approve new scientific ideas before they can be widely accepted					
28. Learning natural sciences changes my ideas about how the world works					

	1 Strongly agree	**2 Agree**	**3 Neutral**	**4 Disagree**	**5 Strongly disagree**
29. To learn natural sciences, I only need to memorize solutions to sample problems					
30. Reasoning skills used to understand natural sciences can be helpful to me in my everyday life					
31. We use this statement to discard the survey of people who are not reading the questions. Please select agree option 2 (not strongly agree) for this question to preserve your answers					
32. Spending a lot of time understanding where formula comes from is a waste of time					
33. I find carefully analysing only a few problems in detail is a good way for me to learn natural science					
34. I can usually figure out a way to solve natural science problems					

35. The subject of natural sciences has little relation to what I experience in the real world					
36. There are times I solve a natural science problem more than one way to help my understanding					
37. To understand natural sciences, I sometimes think about my personal experiences and relate them to the topic being analysed					
38. It is possible to explain natural sciences ideas without mathematical formula					
39. When I solve a natural science problem, I explicitly think about which natural science ideas apply to the problem					
40. If I get stuck on a natural science problem, there is no chance I'll figure it out on my own					
41. It is possible for a scientist to carefully perform the same experiment and get two very different results that are both correct					
42. When studying natural sciences, I relate the important information to what I already know rather than just memorizing it the way it is presented					
43. Learning ecology with puppets is fun					

Adapted and modified from the Colorado Learning Attitude about Science Survey (CLASS) 2006.

Appendix B

The CLASS expert response Key

A =Experts agree or strongly agree.

D =Experts disagree or strongly disagree.

N =There is no consensus expert response.

A only = “Agree” is the only correct answer to this question.

Question	Expert response	Question	Expert response
1	D	22	D
2	A	23	D
3	A	24	A
4	N	25	A
5	D	26	A
6	D	27	D
7	N	28	A
8	D	29	D
9	N	30	A
10	D	31	A only
11	A	32	D
12	D	33	N
13	D	34	A
14	A	35	D
15	A	36	A
16	A	37	A
17	D	39	A
18	D	40	A
19	A	41	D
20	D	42	N
21	D	43	A

The CLASS Expert Response Key to the statements/questions in the pre- and post- attitude survey questions adapted and modified from (Adams et al. 2006:5)

Appendix C

Letter of permission from the Free State Department of Basic Education (FSDoE)

education
Department of Education
FREE STATE PROVINCE

Enquiries: KK Motshumi
Ref: Research Permission: VU Okwara assisted by Dr. JPH Pretorious, Ms Mandisa and Mr G Moemedi
Tel. 051 404 9283 / 9221 / 082 454 1519
Email: K.Motshumi@fseducation.gov.za

VU OKWARA
Dooringboom Street
Mandela View
BLOEMFONTEIN , 9301

082 426 6737

Dear Mr Okwara

APPROVAL TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION

1. This letter serves as an acknowledgement of receipt of your request to conduct research in the Free State Department of Education supported by Dr Pretorius, Ms Mandisa and Mr Moemedi as follows:

   Research Topic: The effectiveness of puppetry in changing teachers and learners attitudes in natural sciences

   [redacted]

   Target Population: 60 Grade 9 natural science learners to be used as experimental group and 60 Grade 9 natural science learners to be used as control group at each of the three schools.

   Period of research: From 8 April 2019 until 30 September 2019. Please note the department does not allow any research to be conducted during the fourth term (quarter) of the academic year nor during normal school hours.

2. Should you fall behind your schedule by three months to complete your research project in the approved period, you will need to apply for an extension.

3. The approval is subject to the following conditions:

   3.1 The collection of data should not interfere with the normal tuition time or teaching process. This means that the "extra classes" with the learners in the control group and in the experimental groups must take place outside normal teaching hours.

   3.2 A bound copy of the research document or a CD, should be submitted to the Free State Department of Education, Room 319, 3rd Floor, Old CNA Building, Charlotte Maxeke Street, Bloemfontein.

   3.3 You will be expected, on completion of your research study to make a presentation to the relevant stakeholders in the Department.

   3.4 The ethics documents must be adhered to in the discourse of your study in our department.

4. Please note that costs relating to all the conditions mentioned above are your own responsibility.

Yours sincerely

DR JEM SEKOLANYANE
CHIEF FINANCIAL OFFICER

DATE: 01/04/2019

RESEARCH APPLICATION OKWARA VU PERMISSION EDITED 29 MARCH 2019
Strategic Planning, Policy & Research Directorate
Private Bag X20565, Bloemfontein, 9300 - Room 318, Old CNA Building, 3rd Floor, Charlotte Maxeke Street, Bloemfontein
Tel: (051) 404 9283 / 9221 Fax: (086) 6678 678

Appendix D

Ethical clearance letter from the ethics committee of the University of the FreeState

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
EDUCATION
OPVOEDKUNDE

[redacted]

Faculty of Education

11-Dec-2018

Dear **Mr Valentine Okwara**

Ethics Clearance: **THE EFFECTIVENESS OF PUPPETRY IN CHANGING TEACHER'S AND LEARNERS' ATTITUDES IN NATURAL SCIENCES**

Principal Investigator: **Mr Valentine Okwara**

Department: **School of Mathematics Natural Sciences and Technology Education Department (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2018/1333**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Prof. MM Mokhele Makgalwa
Chairperson: Ethics Committee

Education Ethics Committee
Office of the Dean: Education
T: +27 (0)51 401 3777| F: +27 (0)86 546 1113 | E: MokheleML@ufs.ac.za
Winkie Direko Building | P.O. Box/Posbus 339 | Bloemfontein 9300 | South Africa
www.ufs.ac.za

Appendix E

Letter of permission to the principals of the participating schools

Valentine Okwara,

PO Box 6584,

Bloemfontein 9300.

12th December 2018.

Dear Sir / Madam,

APPLICATION FOR PERMISSION TO CONDUCT RESEARCH STUDY FOR Ph.D. IN CURRICULUM STUDIES IN YOUR SCHOOL

I would like to ask for your permission for the grade 9 natural science learners in your school to participate in the research that aims to find out how effective the use of puppets as a teaching tool can be in the teaching of ecology in natural sciences as well as how it can be used to positively influence the attitudes of learners towards natural science as a school subject. The title of the research is: **The effectiveness of puppetry art in changing the learners' attitudes towards Natural Science.** Your school is one of the designated secondary schools in the Motheo District of the Free State where data will be collected. It will be conducted as a requirement for a Ph.D. in the field of Curriculum studies from the University of the Free State, in Bloemfontein. The duration of data collection for the study is from April 2019 to September 2019.

During the study, we will assign the learners into two groups: the experimental and control groups. The experimental group will be taught ecology with puppets while the control group will be taught ecology without puppets. Both groups of learners will complete a pre and post attitude survey which will be statistically analysed and compared. The learners are expected to participate during extra classes that will be organised. The content of the research is in line with the stipulations of the CAPS document. In other words, the research will not cause any disruptions in the learners' normal school activity. The necessary documents authorising the conduct of the research i.e. ethical clearance has been granted by the University of the Free State (UFS-HSD2018/1333), and permission from the Free State Department of Education are attached to the letter.

Thanking you Sir / Madam in anticipation of your cooperation

Yours in Education,

Dr JPH Pretorius — Study leader / Supervisor

VU Okwara — Researcher

Appendix F

Informed consent letter to the parents/guardians of the participants

RESEARCH STUDY INFORMATION LEAFLET AND PARENTAL CONSENT FORM

DATE
April to September 2019.

TITLE OF THE RESEARCH PROJECT
The effectiveness of puppetry in changing teacher's and learners' attitudes in natural sciences.

RESEARCHERS NAME(S) AND CONTACT NUMBER:
Okwara, Valentine U 2007084771 0824266737

FACULTY AND DEPARTMENT:
Faculty of Mathematics, Natural sciences, and Technology Education
Department of Education

STUDYLEADER(S) NAME AND CONTACT NUMBER:
DR JPH Pretorius
0833121243

WHAT IS THIS RESEARCH PROJECT ALL ABOUT?
In this research, our aim is to find out how effective the use of puppets as a teaching tool can be in the teaching of ecology in natural sciences as well as how it can be used to positively influence the attitudes of teachers and learners towards natural science. In other to do this, we will assign the learners into two groups: the experimental and control groups. The experimental group will be taught ecology with puppets while the control group will be taught ecology without puppets. Both groups of learners will complete a pre and post attitude survey and write a test at the beginning and end of the study which will be statistically analysed and compared.

WHY HAVE YOUR CHILD BEEN INVITED TO TAKE PART IN THIS RESEARCH PROJECT?
Your child have been invited to take part in this study because he/she is a grade 9 learner, and also his/her participation will actually help us to determine if using puppets to teach ecology will be effective in changing the learners' and teacher's attitudes towards natural science and making them learn better.

WHO IS DOING THE RESEARCH?
Mr. Valentine Okwara, a science educator working for the Free State Department of Education.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?
This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: UFS-HSD2018/1333

WHAT WILL HAPPEN TO YOUR CHILD IN THIS STUDY?
Your child will be one of the learners who will be taught ecology in natural sciences using puppets as a teaching tool if he / she is selected in the experimental group or he / she will be taught ecology without using puppets as a tool if they fall within the control group in their classroom.

CAN ANYTHING BAD HAPPEN TO YOUR CHILD?
No, nothing bad will happen to your child, he/she will only be a learner in the classroom learning ecology being taught using puppets as a tool or he/she will be taught ecology without using puppets depending on the group he/she falls into e.g. experimental or control group. After the teaching and learning all of them will answer questions that will test if the puppets had an effect in the teaching of ecology when their responses and test scores are compared.

CAN ANYTHING GOOD HAPPEN TO YOUR CHILD?
Yes, he/she might develop positive attitudes towards natural science and learn better if the research proves that puppets helps learners to develop positive attitudes towards science and makes learning science easier.

WILL ANYONE KNOW YOUR CHILD IS PART OF THE STUDY?
No, the child's participation will remain confidential; this means that no one will know that your child took part in the research.

WHO CAN YOU TALK TO ABOUT THE STUDY?
You can talk to Dr JPH Pretorius of the University of the Free State on 0833121243
or VU Okwara on 0824266737

WHAT IF YOU DO NOT WANT YOUR CHILD TO DO THIS?
The child can decide whether he/she wants to be part of the study, if he/she is interested or he/she can decide not to participate even when you have given your approval.

PLEASE RETURN

April – September 2019
Date; Saturday ……………………………………. 2019

Name of child: ____

Name of Parent: ____

- Do you understand this research study and are you willing to let your child take part in it? Yes ☐ No ☐
- Has the researcher answered all your questions? Yes ☐ No ☐
- Do you understand that you can withdraw your child from the study at any time? Yes ☐ No ☐
- I give the researcher permission to make use of the data / photos gathered from my child's participation. Yes ☐ No ☐

___________________________________ ___________________________

Signature of Parent ***Date***

Appendix G

Informed consent letter (Assent letter)

RESEARCH STUDY INFORMATION LEAFLET AND LEARNER ASSENT FORM

DATE
April to September 2019.
TITLE OF THE RESEARCH PROJECT
The effectiveness of puppetry in changing teacher's and learners' attitudes in natural sciences

RESEARCHERS NAME(S) AND CONTACT NUMBER:
Okwara, Valentine U   0824266737

FACULTY AND DEPARTMENT:
Faculty of Mathematics, Natural Sciences and Technology Education
Department of Education

STUDYLEADER(S) NAME AND CONTACT NUMBER:
DR JPH Pretorius
0833121243

WHAT IS THIS RESEARCH PROJECT ALL ABOUT?
In this research, our aim is to find out how effective the use of puppets as a teaching tool can be in the teaching of ecology in natural sciences as well as how it can be used to positively influence the attitudes of teachers and learners towards natural science. In other to do this, we will assign the learners into two groups: the experimental and control groups. The experimental group will be taught ecology with puppets while the control group will be taught ecology without puppets. Both groups of learners will complete a pre and post attitude survey, and also write a test at the beginning and end of the study which will be statistically analysed and compared.

WHY HAVE YOU BEEN INVITED TO TAKE PART IN THIS RESEARCH PROJECT?
You have been invited to take part in this study because you are a grade 9 learner, and also your participation will help us to determine if using puppets to teach ecology will be effective in changing learners' and teacher's attitudes towards natural science and making them learn better.

WHO IS DOING THE RESEARCH?
Mr. Valentine Okwara, a science educator working for the Free State Department of Education.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?
This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: UFS-HSD2018/1333

WHAT WILL HAPPEN TO YOU IN THIS STUDY?
You will be one of the learners who will be taught ecology in natural sciences using puppets as a teaching tool if you are selected in the experimental group or you will be taught ecology without using puppets as a tool if you fall within the control group in your classroom.

CAN ANYTHING BAD HAPPEN TO YOU?
No, nothing bad will happen to you, you will only be a learner in the classroom learning ecology being taught using puppets as a tool or you will be taught ecology without using puppets depending on the group you fall into e.g. experimental or control group. After the teaching and learning all of you (learners) will answer questions that will test if the puppets had an effect in the teaching of ecology when your responses and test scores are compared.

CAN ANYTHING GOOD HAPPEN TO YOU?
Yes, you might develop positive attitudes towards natural science and learn better if the research proves that puppets helps learners to develop positive attitudes towards science and makes learning science easier.

WILL ANYONE KNOW YOU ARE PART OF THE STUDY?
No, your participation will remain confidential; this means that no one will know that you took part in the research.

WHO CAN YOU TALK TO ABOUT THE STUDY?
You can talk to Dr JPH Pretorius of the University of the Free State on 0833121243 or VU Okwara on 0824266737

WHAT IF YOU DO NOT WANT TO DO THIS?
You can decide whether you want to be part of the study, if you are interested or you can decide not to participate even when your parent or guardian have given his / her approval.

- Do you understand this research study and are you willing to take part in it? Yes ☐ No ☐
- Has the researcher answered all your questions? Yes ☐ No ☐
- Do you understand that you can withdraw from the study at any time? Yes ☐ No ☐
- I give the researcher permission to make use of the data / photos gathered from my participation Yes ☐ No ☐

ASSENT

I, ____ hereby agree to participate in the research. I have read and understand the information provided by the researcher above.

________________________________ ________________________

Signature of LEARNER ***Date***

Appendix H

Descriptive Statistics for individual questions in the attitude survey

Descriptive Statistics Each question					
		Period			
		Post		Pre	
		Group		Group	
		Control	Experimental	Control	Experimental
Q_1	N	169	180	174	178
	Mean	0,349	0,067	0,075	0,090
Q_2	N	171	178	171	180
	Mean	0,795	0,82	0,795	0,894
Q_3	N	170	177	173	178
	Mean	0,606	0,718	0,601	0,618
Q_4	N	178	180	178	180
	Mean	0	0	0	0
Q_5	N	174	180	174	180
	Mean	0,328	0,272	0,322	0,3
Q_6	N	167	177	170	177
	Mean	0,419	0,299	0,412	0,322
Q_7	N	178	180	178	180
	Mean	0	0	0	0
Q_8	N	174	177	173	178
	Mean	0,264	0,113	0,266	0,174
Q_9	N	178	180	178	180
	Mean	0	0	0	0
Q_10	N	167	177	169	176
	Mean	0,257	0,282	0,26	0,29
Q_11	N	168	177	171	177
	Mean	0,667	0,723	0,649	0,723
Q_12	N	175	180	175	180
	Mean	0,171	0,15	0,171	0,161
Q_13	N	175	178	175	178

	Mean	0,469	0,287	0,469	0,376
Q_14	N	173	179	173	178
	Mean	0,815	0,816	0,815	0,781
Q_15	N	173	178	172	175
	Mean	0,699	0,73	0,698	0,72
Q_16	N	171	176	171	177
	Mean	0,643	0,67	0,643	0,616
Q_17	N	172	178	172	179
	Mean	0,151	0,101	0,151	0,117
Q_18	N	171	177	171	173
	Mean	0,275	0,141	0,275	0,15
Q_19	N	172	180	171	175
	Mean	0,791	0,756	0,795	0,68
Q_20	N	173	179	173	179
	Mean	0,283	0,235	0,283	0,324
Q_21	N	170	176	170	176
	Mean	0,476	0,273	0,471	0,307
Q_22	N	172	178	171	176
	Mean	0,233	0,174	0,234	0,199
Q_23	N	172	179	171	176
	Mean	0,395	0,358	0,398	0,386
Q_24	N	174	177	173	178
	Mean	0,713	0,774	0,717	0,736
Q_25	N	163	176	171	175
	Mean	0,699	0,682	0,667	0,606
Q_26	N	172	175	173	173
	Mean	0,419	0,549	0,416	0,457
Q_27	N	175	180	175	177
	Mean	0,171	0,111	0,171	0,107
Q_28	N	174	180	174	178
	Mean	0,747	0,833	0,747	0,809
Q_29	N	173	179	173	178
	Mean	0,075	0,073	0,075	0,129
Q_30	N	173	179	173	176
	Mean	0,74	0,743	0,746	0,699
Q_31	N	175	175	175	173

	Mean	0,8	0,257	0,806	0,225
Q_32	N	174	177	174	178
	Mean	0,552	0,497	0,552	0,590
Q_33	N	178	180	178	180
	Mean	0	0	0	0
Q_34	N	171	175	171	173
	Mean	0,608	0,697	0,608	0,601
Q_35	N	171	176	171	177
	Mean	0,228	0,148	0,228	0,169
Q_36	N	171	177	170	177
	Mean	0,637	0,706	0,641	0,616
Q_37	N	174	178	173	177
	Mean	0,644	0,708	0,647	0,627
Q_38	N	170	180	170	178
	Mean	0,529	0,472	0,529	0,41
Q_39	N	168	180	168	174
	Mean	0,565	0,656	0,565	0,598
Q_40	N	173	177	173	175
	Mean	0,405	0,356	0,399	0,337
Q_41	N	178	180	178	180
	Mean	0	0	0	0
Q_42	N	174	177	172	177
	Mean	0,667	0,757	0,674	0,689

Appendix I

Puppet scripts 1, 2, and 3.

SENIOR PHASE NATURAL SCIENCES

GRADE 9

PUPPET SCRIPT 1

TOPIC; BALANCE IN AN ECOSYSTEM

AIMS: (i) To evaluate the impact of various factors such as loss of habitat, loss of species and climate change on the ecosystem

(ii) To understand the effects of loss of habitat: extinction of species and change of climate on the ecosystem.

(iii) To provide context for further study on the effects on food web when one organism is removed from the food chain.

KEY:

N = Nathi, the Ecologist

G = Gloria

T = Teacher

	Conversation	**Comments**
G	Nathi, you look so worried…is everything ok?	Gloria looking concerned…
N	Morning Gloria, I am thinking about the ecosystem and also worried about the future of the ecosystem.	Nathi obviously concerned.
G	Why are you worried about the future of the ecosystem?	
N	Well, the ecosystem is organised in a state of balance where species co-exist….	Nathi is interrupted by Gloria's enthusiastic question…
G	What is this ecosystem you are talking about?	
N	I will simplify my answer so that you will understand it very well Gloria…An ecosystem is a habitat in which animals,	

	plants and micro-organisms interact with non-living factors such as landscapes, temperature etc.	
G	Mmm, (Gloria thinking) …so why is it important?	Gloria looks confused
N	…Healthy ecosystems clean our water, purify our air, maintain our soil, regulate the climate, recycle nutrients, and provide us with food. They also provide raw materials and resources for medicines and other purposes.	Nathi continues to explain…
G	So why are you worried about the ecosystem if it has all these benefits?	
N	Actually, am worried about the balance in the ecosystem	
G	What balance are you referring to Nathi?	Gloria is inquisitive
N	A balanced ecosystem maintains the flow of materials and energy. The disruption of the balance and its consequences worries me…	
G	I think am trying to understand you now Nathi…you mean a balanced ecosystem provide us with all the benefits you mentioned, right? therefore disrupting the balance will also affect us, but what can disrupt the balance in the ecosystem?	
N	Natural or human induced factors can directly or indirectly cause a change in an ecosystem. These factors are called drivers. A direct driver such as habitat change can influence ecosystem processes…apart from this, pollution can also affect the ecosystem by altering the basic ecosystem functions such as plant growth which influences the benefits humans get from the environment such as timber, clean drinking water etc.	
G	Wow tell me more Nathi, this is very interesting…	
N	Yes Gloria, the impact of ecosystem destruction can lead to climate change leading to increased flooding due to the erosion of the soil and lack of trees, rising sea levels due to the melting of the glaciers caused by global warming and the disruption of the food chain as well as the loss of species due to extinction.	
G	This is really worrying Nathi…	
N	Yes Gloria, loss of habitat in simplest terms is when a habitat is destroyed, the plants, animals and other organisms that occupied the habitat will have reduced carrying capacity which will cause their population to decline and they might be extinct, perhaps the greatest threat to organisms is habitat loss…	Nathi continues to explain…
N	You will agree with me Gloria that increased food production (human activity), is a major agent for the conversion of natural habitat into agricultural land. Forest lost and degradation is mostly caused by the expansion of agricultural land, intensive harvesting of timber, wood for fuel and other forest products as well as over grazing!	

G	Nathi am really getting worried after hearing all these things you are saying.	
N	It is worrying Gloria…because unbalanced ecosystem can also have an impact on the food chain and food web when one of the organisms is removed due to extinction. For an example, if the herbivores are removed from the food web, there will not be food for the carnivores and the population of the producers will be out of control.	
G	Nathi, this is really scary!!	Gloria is really looking worried.
N	Actually, humans play a key role in maintaining ecological balance because they have the highest thinking capacity as compared to other living organisms	
G	Really?	Gloria is looking reassured
N	Yes Gloria…ecological balance is important because it leads to the continuous existence of the organisms, it ensures that no particular species is exploited or overused.	
G	What then can humans do to ensure that ecological balance is maintained? Since they play a key role?	
N	If we humans can change our everyday lifestyle, you and I can help to protect the planet and its ecosystem.	
G	Please, Nathi, how can we do this?	Gloria is excited…
N	First of all, we can help by reducing or eliminating the use of household chemicals and pesticides that can hurt the environment because chemicals can leak into ecosystems when they are disposed. Secondly, by planting trees and using less fertilizer. Thirdly, by reducing our waste, reusing products and recycling disused recyclable products. Fourthly, we can volunteer to clean up our communities and educate the people about the importance of maintaining a healthy balance in the ecosystem.	
G	How can we reduce the impact of habitat loss and the loss of species in the ecosystem Nathi?	Gloria looking reassured…
N	We can preserve existing wetlands as they provide valuable habitat for birds, fish, amphibians, and mammals. These areas also help to filter and store water and protect the shoreline from erosion and wave damage. We can also plant indigenous trees around our homes and properties!	
G	I am happy and relieved that we can play a role in maintaining the balance in the ecosystem by adhering to your advice Nathi, if only we can start now to take care of our environment, we will preserve the ecosystem that provides us with everything!!	
N	Yes Gloria, we cannot afford to destroy the very same ecosystem that sustains our life, I don’t think it’s wise.	
G	I agree with you Nathi, it’s not wise!!	

T	Learners, can you think of any other factor that can disrupt the balance in the ecosystem?	Teacher provides learners with a chance to respond
G	Nathi, I can think of climate change	
N	That's correct, climate change can cause an imbalance in the ecosystem because it can lead to flooding which disrupts the ecosystem	Teacher acknowledges learner answer
G	Nathi, thank you for educating me and keeping me informed about our ecosystem, I am now empowered and ready to educate others so that together we can reverse the imbalance that threatens our ecosystem.	
T	After everything we have learned today, it is time to do a very interesting investigation on the ecosystem…	The teacher introduces the topic of the investigation on the impact on the food chain when one organism is removed from the trophic level.

SENIOR PHASE NATURAL SCIENCES

GRADE 9

PUPPET SCRIPT 2

TOPIC; CONSERVATION OF THE ECOSYSTEM

AIMS; 1. To create awareness on the importance of maintaining biodiversity and sustainable use of natural resources.

2. To highlight irresponsible human practices such as inappropriate refuse disposal and Their impact on the ecosystems.
3. To provide possible solutions to the irresponsible human practices.
4. To provide context for the study of ecosystems within the school yard.

KEY:

N = Nathi, the Ecologist

G = Gloria

T = Teacher

	Conversation	**Comments**
G	Good morning Nathi, how are you today? Is there anything new for me to learn today?	Gloria is looking enthusiastic…
N	Morning Gloria, today I am going to make you aware of how important it is for us to maintain biodiversity and use natural resources sustainably!	Nathi is eager to engage Gloria on sustainable use of natural resources…
G	…Did I hear you say biodiversity? What does that mean? And what is the meaning of “sustainable use” of natural resources?	Gloria is inquisitive…
N	Yes Gloria, biodiversity is the amount of life on earth and…	
G	Why is biodiversity important?	Gloria interrupts with a question…
N	…It is important because biodiversity boosts ecosystem productivity where each species, no matter how small, all have important role to play. For example, a larger number of plant species means greater variety of crops. Greater species diversity ensures natural sustainability for all life forms.	
G	I wouldn’t have known all these! Where did you get all this information Nathi?	Gloria looks concerned…
N	…Have you forgotten that I am an Ecologist?	
G	That is awesome Nathi, I thought an Ecologist is a person who studies about “echo”? Hence the name “echologist”?	
N	Hahahahaha… Gloria, the name is not “echologist” we do not study “echo”, the name is ecologist, we study the environment that is why I know so much about the environment and I hope you will learn a lot too…	Nathi laughs out loud, on Gloria’s naïve question and is prepared to educate her more…
G	I would also like to learn from you Nathi, please continue…	Gloria chips in…
N	Thank you Gloria, as I was saying earlier, the maintenance of biodiversity is very important because a healthy ecosystem cleans our water, purify our air, maintain our soil, regulate climate, recycle nutrients and provide us with food… apart from all these, it provides raw materials and resources for medicine and other purposes.	Nathi continues…
G	Wow… that sounds interesting...	

N	Yes Gloria…knowledge is gained through awareness, that is why I am making you aware of the importance of maintaining biodiversity and the sustainable use of natural resources, so that we will stop harming the environment and the ecosystem.	
G	…Did you say "sustainable use" of natural resources? How?	Gloria looks concerned.
N	Yes Gloria, sustainable use of natural resources means the use of components of biodiversity in a way and at a rate that does not lead to long time decline of biodiversity, thereby maintaining its potential to meet the needs and aspirations of future generations.	Nathi explains to Gloria the meaning of sustainable use…
G	I think I understand it very clearly Nathi, you are really an Ecologist!	
N	Exactly so Gloria, in a very simple term we shouldn't "overuse" biodiversity! I am glad you understood my explanations.	
G	So, what are the benefits of this biodiversity that we must not over use?	Gloria is inquisitive…
N	Thank you for that question Gloria, I hope you will become an ecologist someday… the benefits are a lot, for example, pollinators including bees and butterflies provide significant environmental economic benefits to agricultural and natural ecosystems including adding diversity and productivity to food crops, as many as one in three of the world's food production relies directly or indirectly on insect pollination!!	
G	That is incredible Nathi, so without the insects like bees and butterflies we will not be able to have some of our agricultural products? So we shouldn't kill these insects?	Gloria is learning something new…
N	Exactly my point Gloria, am glad you understand why we should preserve biodiversity… did you know that biodiversity plays a crucial role in human nutrition through its influence on the world food production, as it ensures the sustainable productivity of soil and provides the genetic resources for all crops, livestock and marine species harvested for food?	
G	I wouldn't have known that, Nathi…	
N	Yes indeed, by securing the life sustaining goods and services which biodiversity provides us, the conservation and sustainable use of biodiversity can provide significant benefits to our health…without a global environment that is healthy and capable of supporting a diversity of life, no human population can exist!!!	Nathi emphasises the importance of sustainable use of biodiversity…
G	This is unbelievable Nathi…we live in an interconnected world where biodiversity is king!	
N	Hahahaha Gloria… I agree with you, did you also know that biodiversity recycle carbon, fix nutrients and enable plants to grow and feed us? It also keeps pest species and diseases in check and help to protect against flooding and regulate the climate! Biodiversity is king indeed as you said!	Nathi consolidates Gloria's idea…
G	Wow, this is incredible!	Gloria is excited…

N	That is the reason why it is very important for us to create awareness on the need to maintain biodiversity and use natural resources sustainably…	Nathi emphasises the importance maintaining biodiversity.
G	I totally agree with you Nathi.	Gloria chips in…
N	Thanks Gloria, I think it is equally important for me to highlight some irresponsible human behaviour which might affect biodiversity and may lead to loss of biodiversity… one of these is irresponsible waste disposal.	
G	Please Nathi, what do you mean by "loss of biodiversity" as you mentioned? Is it "lost" like I lost my pencil last week but later found it?	Gloria looks confused.
N	Hahahaha... not really Gloria, "loss of biodiversity" is the extinction of species (both plants and animals), and also the disappearance of species in a certain habitat. Once disappeared they are lost forever!	Nathi explains…
G	Ok I got it Nathi…but what will cause that?	
N	…The same irresponsible human activities in the environment as I mentioned earlier like inappropriate refuse disposal…	Nathi concludes.
G	How can that be? What is the relationship between inappropriate waste disposal and extinction of species? I don't get it.	Gloria is still confused.
N	Thank you, Gloria, first, let us look at inappropriate refuse disposal and the consequences that might lead to the extinction of species. If we reduce the amount of waste we generate, we can reduce the amount of methane gas released from landfills, which will slow down climate change that leads to loss of biodiversity. Secondly, some of the wastes we generate will not decay and, in this instance, may help to generate gases that cause greenhouse effect. Thirdly, if wastes are inappropriately disposed, it may cause soil, air and water pollution. This contributes to the creation of greenhouse gases which may harm marine and wildlife…Can you see with me how inappropriate waste disposal could lead to loss of biodiversity and extinction of species?	
G	Yes Nathi, you are right, but isn't there anything we can do to stop the loss? I wouldn't want biodiversity to disappear after hearing all the benefits!!!	Gloria is not feeling fine…
N	…indeed Gloria, we can do something to prevent further loss of biodiversity, it is very simple! Change our behaviour towards waste management.	
G	Really? But what do you mean...how can we change our behaviour?	
N	Well Gloria, we can reduce the use of harmful products, reduce the number of plastic bags we use, reduce the amount of garbage as well as the paper we use! We can also purchase items made from recycled products or	

	packaged in recycled package materials. Not only these, we can also re-use them!	
G	Wow, this sounds simple Nathi… it is doable!	Gloria is relieved to learn that there is realistic solution to the threat…
N	Yes Gloria, it is doable! It is equally very important for us to preserve our ecosystem and biodiversity; we do not have any other home except planet earth! If we can change our behaviour towards waste management, we will contribute in no small way towards achieving our goal of conserving the ecosystem.	
G	You are very right Nathi, inappropriate disposal of waste has a huge impact on the environment which can negatively affect biodiversity. Thanks, Nathi for this awareness, I will also share this information with my friends, together we can contribute in no small way towards preventing loss of biodiversity! Thanks for all the information; I have really learned a lot from you today. Goodbye Nathi.	
N	Goodbye Gloria	
T	Children, I hope you have learned important things about biodiversity and more importantly how we can conserve our ecosystem and preserve further loss of biodiversity and extinction of species… It is now time for us to apply the knowledge we have acquired to answer some of the questions relating to conservation of an ecosystem…	Learners prepare for classwork

SENIOR PHASE NATURAL SCIENCES

GRADE 9

PUPPET SCRIPT 3

TOPIC: FEEDING RELATIONSHIPS; FOOD CHAIN AND FOOD WEB

AIMS:
1. To classify selected examples of organisms into their respective feeding groups e.g. Herbivores, Carnivores and Omnivores.
2. To identify food chains and food webs in different ecosystems.

KEY

N = Nathi, the ecologist

G = Gloria

T = teacher

	Conversation	**Comments**
G	Good morning Nathi, am very excited to be here today…	
N	Good morning Gloria, today we are going to learn about feeding relationships and feeding groups in the ecosystem.	
G	…wow that will be very interesting, I have been learning a lot from you lately…	
N	Yes, feeding relationships and feeding groups tells us how organisms get their food in the ecosystem and also the different groups into which we can classify them. In ecology we call these food chain and food web.	
G	Wow, how can food be a chain or a web? I thought webs are made by spiders!	Gloria is a bit confused…
N	Hahaha…not that chain or web you know, this "food chain" actually is a diagram that shows how nutrient and energy is passed from one organism to the other, we use arrows to show how different groups of organisms are connected in the feeding relationships…in other words it shows who eats whom in the ecosystem!	Nathi laughs and explains…
G	Who eats whom? That sounds ridiculous Nathi…	
N	Not really, Gloria… in the ecosystem all organisms depend on one another for food and survival…this means that the organisms must eat one another in other to survive. The trend of how this happens is represented by the food chain and that simply shows who feeds on whom or "who eats whom"!	
G	Ok I think I understand it much better now, Nathi, this is very interesting	
N	Yes Gloria, the food chain begins with plant-life and ends with animal-life. In a food chain, energy is passed from the sun to the producers, from the producers to the consumers and from the consumers to the decomposers.	
G	What do you mean by producers, consumers and decomposers?	
N	The producers are the plants, they are called the Autotrophs because they have the ability to trap the energy from the sun and use it to make their own food during a process called photosynthesis. This food is passed on to the consumers. The consumers are the animals; they are called heterotrophs because they cannot make their own food, and so depend on the producers for food. We have three categories of consumers, the primary consumers or herbivores and the secondary consumers or the carnivores	

	and the tertiary consumers or omnivores. The herbivores feed directly on the plants, the carnivores feed on flesh while the omnivores feed on both plants and flesh. The decomposers are the fungi that breakdown and recycle the dead remains of plants and animals.	
G	That's interesting…	
N	Exactly, the green plants e.g. grass are the producers, animals such as sheep, cow, goat, antelope etc. are the herbivores, Lion, tiger, cheetah etc. are the carnivores while animals such as pigs and humans are the omnivores.	
G	Wow … so who eats whom?	
N	Good question Gloria… plants and algae which use energy from the sun to make their own food sit at the bottom of the food chain, they are the producers. The herbivores: sheep, goat, antelope etc. eat the grass: the carnivores; lion, tiger, cheetah, eat the antelope: while the omnivores; pig, bear and humans, eat both meat and plants!	
G	I now understand who eats whom in the food chain…can the antelopes eat the lion?	
N	No, the antelopes are herbivores they can only eat grass.	
G	Ok Nathi, I think I understand you; the herbivores only eat plants and carnivores only eat flesh or meat?	
N	Yes, you are correct Gloria.	
G	So, the plants make their food using sunlight and chlorophyll during photosynthesis. The energy is passed on to the herbivores when they eat the plants, and the energy is further passed on to the carnivores when they eat the herbivores and the omnivores get their energy when they eat plants or flesh?	
N	Well said Gloria I am glad you are able to understand the food chain perfectly. Congratulations!	
G	Thank you Nathi for being patient with me.	
N	Now that you have learned about the food chain, let us look at food chains in different ecosystems.	
G	That will be very interesting Nathi, I am listening…	
N	Ok, there are two main types of ecosystems; these are – Terrestrial ecosystem and Aquatic ecosystem. Terrestrial ecosystems are found on land while Aquatic ecosystems are found in a body of water. Aquatic ecosystem can further be divided into Marine and Fresh water ecosystems. Aquatic ecosystems contain a variety of life forms including fungi, protozoa, free-floating microscopic plants and animals called plankton, other large plants and fish.	
G	Wow, that's cool, is that all about the ecosystems?	Gloria is inquisitive
N	No Gloria, the freshwater ecosystems are three types; Lentic ecosystem which includes pools, ponds, and lakes: Lotic ecosystem which includes streams, and rivers as well as Wetlands which includes areas where the soil is saturated with water. The marine ecosystem includes	Nathi explains the types of aquatic ecosystems…

	saltmarshes, mudflats, mangrove swamp and coral reefs. In these ecosystems, the food chains still follow the same pattern as terrestrial ecosystems, this means that the producers trap energy from the sun and use it to make food which is eaten by the herbivores and the herbivores are eaten by the carnivores and the omnivores eat both meat and plants.	
G	Really? So Nathi, if the food chain follows the same pattern as the terrestrial ecosystems as you explained which are the producers in the aquatic ecosystem?	Gloria asks…
N	Good question Gloria, the producers are the phytoplankton. Phytoplankton is simply microscopic floating plants!	Nathi explains…
G	Wow, which are the herbivores?	
N	The herbivores include but not limited to the surgeon fish, parrot fish, green turtles and manatees.	
G	Interesting, what of the carnivores?	
N	These include fish, leopard seals, penguins etc.	
G	…and the omnivores?	
N	The omnivores include the Baleen whale.	
G	Thanks a lot, Nathi, you are such a knowledgeable ecologist!	
N	Thank you, Gloria.	
G	I have learned that the herbivores, for example the antelope cannot eat the lion, rather the lion eats the antelope in the food chain.	
N	That's correct Gloria. Who can give us another example of who eats whom in the aquatic food chain…?	
T	Learners can you think what the answer could be?	
G	Nathi, I think the parrot fish eats the phytoplankton and the penguins eat the parrot fish.	
N	That is correct, the herbivores eat the producers and the carnivores eat the herbivores.	
T	Learners I hope you have learned how to classify organisms into different feeding groups in the food chain and the different examples of each, as well as how to draw food chains and food webs in both the terrestrial and aquatic ecosystems, now we have to do an exercise to see how many of these organisms you will be able to classify.	Teacher hands out the worksheet to the learners.